IRC:SP:50-2013

GUIDELINES ON URBAN DRAINAGE

(First Revision)

INDIAN ROADS CONGRESS
2013

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GUIDELINES ON URBAN DRAINAGE

BACKGROUND

The Guidelines for Urban Drainage was first published in 1999. With the change in urban infrastructural concepts and introduction of new transportation infrastructures like metro rails, multilevel interchanges, elevated corridors, the Urban Roads Streets and Transport Committee (H-8) felt the need of revising the Guidelines to meet the challenges of future. A sub-committee comprising S/Shri R. Jai Prasad, R.K. Jaigopal and Dr. B.P. Bagish prepared the draft revision of IRC:SP:50 'Guidelines on Urban Drainage' which has been deliberated since 2009.The H-8 Committee discussed the draft in series of meetings and approved the same in its meeting held on 29th September, 2012 for placing before the Highways Specifications and Standards Committee. The HSS Committee approved the draft document in its meeting held on 13th December 2012 for placing before the Council. Finally the Council in its meeting held at Coimbatore (Tamil Nadu) on 8th January, 2013 considered and approved the draft document subject to incorporation of comments of the Council Members. Accordingly, H-8 Committee again discussed and approved the draft document in its meeting held on 2nd March, 2013 for placing before the HSS Committee. The Highways Specifications and Standards Committee (HSS) in its meeting held on 19th July, 2013 approved the document for publishing.

The composition of H-8 Committee is as given below:

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1 INTRODUCTION

1.1 Urban drainage is an integral part of road network for disposal of surface and subsurface water to designated locations. Structural integrity of road mainly depends on effective and efficient disposal of storm water. The increased volume and velocity of runoff being caused by increased impervious urban development of the city can easily overwhelm the existing conventional drainage systems of the city. Decentralized stormwater management along streets and public places in different locations shall help in mitigating problems of flooding and water logging on the roads.

Urban drainage system is to be designed such that, they capture the storm water runoff, from the road surface and right-of-way and infiltrate it into the ground closest to the source, where it is falling. In case, there is lack of space, it should be conveyed along the right-of-way and discharged at receiving body, in addition to infiltrate it in to below ground at designated locations only. The load on drainage will reduce, if infiltration into ground is effective. The infiltration shall happen even while conveying and disposing effectively, and will also recharge the depleting ground water table which is alarmingly going low due to intensive urbanization, paving of roads and private properties.

The urban drainage can be detailed into:

i) Road surface drainage

ii) Sub soil drainage

iii) Infiltration into the ground for recharging of ground water table.

iv) Disposal of storm water.

i) **Road surface drainage:** It is an important factor to remove all the water from road surface at the least possible time, so that structural integrity of overall cross-section of the road is maintained, good riding quality of road will enable in saving vehicle operation cost, if surface runoff, of rain water is efficient. The study of pavement drainage for both flexible and rigid pavements has resulted in arriving at a decision that the construction shall be treated as a series of permeable layers and added precautions are necessary to protect the sub-grade. All structural elements of road from wearing coat to sub-grade, footpath etc. will deteriorate leading to major maintenance, if efficiency of disposal system is inadequate. One major cause of pothole formation on road surface is due to inadequate storm water disposal mechanism. In the event of road profile is not constructed with necessary camber and maintained to desired standards, the disposal of rain water will not be quick and efficient, resulting in pooling of water on the carriageway, deteriorating the pavement cross-section, leading to skidding, hydroplaning or splashing of water, which will result in causing inconvenience to other vehicles in addition to self-driven vehicle, causing accidents.

ii) **Sub soil drainage:** Most of the sub soil drainage locations are localized. This water shall be collected by subsurface drainage systems which in turn discharge into a drainage system clear of road formation. Methods of investigation for estimating rates of surface water infiltration ground water levels and flows form an important part of the engineering of a drainage system. Use of self draining materials and introduction of membrane has helped control the migration of fine particles from sub-grade specially while pumping, as relatively small migration of fines from sub-grade into voids in the sub-base can seriously reduce the capacity of the sub-base to act as a lateral drain. The sub soil drainage shall be sustainable for stability of pavement within design parameters. Highest precaution shall be exercised when water logged soil below sub-grade may cause serious damage to the road crust.

iii) **Infiltration into the ground for recharging of ground water table:** The storm water disposal system will be highly efficient, if infiltration into the ground is made a part of urban drainage. The primary advantage will be reduction in quantum of water at final disposal location. Secondary advantage will be recharging urban ground water which is depleting at alarming rate. Infiltration of storm water shall commence at street drains and shall be continued all along conveying system. Different suitable mechanisms shall be adopted for infiltrations, like providing filter mediums of certain length or providing filter bed at alternate junctions etc. Infiltration will also take place at detention and retention facilities where storm water can be controlled qualitatively and quantitatively. In the present state of rapid urbanization, this method will assume greater significance in the Indian content as storm water needs to be conserved while it is made to run off.

iv) **Disposal of acceptable quality of water:** In the present scenario of rapid urbanization, the adverse impact of development activity needs to be mitigated. Urban storm water management practice has to be employed for benefit of storm water control and pollutant removal capabilities. Water quality practices shall be adopted of acceptable standards while disposing off of storm water. Generally, urban storm water management practice shall adopt high pollutant removal for non soluble particles pollutants such as suspended sediments. In the global scenario of recycling of available water, continuous disposal of contaminated water will seriously jeoparadise the availability of potable water. In such circumstances, addition of recycled water to available fresh water is becoming a popular option and is in existence in a few parts of the world. All possible efforts shall be made for continuous and constant removal of pollutants in the drainage system. All available open tanks, parks, nearby quarry pits shall be modernized effectively and utilized as detention and retention ponds and new additional ponds in the flow stream shall be created and added.

Urbanization of any locality and population needs well engineered surface and subsurface drainage system. In the present day context of depletion of water table, the storm water drainage shall be effectively utilized for ground water charging. Water from the road flows to the road side drain through inlets and gratings. For effective drainage, this should join the peripheral drains, which in turn should join the main or trunk drain for ultimate discharge to the natural drain or detention facility or retention facility. Storm water drainage, needs to take into account alignments, levels on ground and outfall levels. Existing drains pass through highly developed and thickly populated areas. As such, there may be a problem of availability of land for increasing capacity of drains, further. Also, the problem of availability of land, for effective disposal of storm water, may not be possible due to non availability of further land. Besides these, drains shall be able to cater to the increased discharge due to continuous addition of new colonies and urbanization. In such situations, the most effective method of disposal of storm water would be by way of disposal into permeable strata of ground at all possible locations in drain itself or at vertical drains specially built for the purpose. An important aspect of drain is to ensure a good velocity in the drain not only when the drain is flowing full but also when the drain is partially full. Usually, silt and other materials collect in the bed in large quantities and necessary silt traps shall be designed at frequent intervals for periodic removal of the same. The design needs to be made to ensure self cleaning velocity during dominant and lean flow conditions.

In most of the urban areas, responsibility for design and construction of peripheral and trunk drainage system rests with local bodies, i.e., Bruhat Nagara Palike, Nagara Palike, Municipalities etc., while that of the road side drain with the road construction agency like PWD. For an effective implementation of drainage system, proper co-ordination between all concerned agencies is compulsory.

v) Poor Drainage results in losses, direct and indirect in the form of damaged roads, reduced serviceability and serious health hazards to general public. Greater awareness on the subject is visible. Importance of planning, organization, fund allocation and monitoring is taking place among urban conglomerates in recent times in the country. Need has been felt to modernize and update the drainage system. There are serious efforts made towards identification and separation of sewerage drains and storm water drains. Immediate and all out efforts are required to separate these two drains or else environment will seriously and permanently be damaged leading to urban catastrophe. This will be important and serious issue for environmentalists.

Under no circumstances, sewerage shall be allowed to flow in storm water drains in any part of urban areas.

Keeping in view a large scale development in urban front in the country and keeping in pace with higher improvement in economic growth relatively to earlier decades coupled with large scale importance given to this sector by the Government, it is felt that the earlier publication IRC:SP:50-1999 needs revision. Drainage and urban roads require to deal with complex situations and parameters in the present changed context. It is, therefore, felt necessary to bring out detailed guidelines dealing with drainage of urban roads.

2 SCOPE

The guidelines covered under this revised publication deal with drainage of urban roads running through plain and rolling areas. The details covered in the revision are the influence of road features, drainage of surface, subsurface and drainage at special locations like rotaries, vehicular underpasses, parking lots, etc. Design aspects of storm water drains, detention and retention facilities for disposal of storm water are covered. Details of pumping have been dealt separately. Due to rapid urbanization, infiltration of rain water into the sub soil has decreased drastically and recharging of ground water has diminished. Special emphasis on ground water recharging and rain water harvesting is laid and a new chapter is now included. Urban water quality requirements while final disposal of storm water is also covered. Enforcement for maintenance of drains is added as a separate chapter due to its prime importance. A new chapter on geographical information system has been added for better planning of storm water drains. The drainage of rural section of roads, hill roads, airfield pavements and cross drainage have not been covered under these guidelines since separate guidelines in IRC:SP:42-1994 on these subjects have been published.

3 ROAD SURFACE DRAINAGE

3.1 Traffic safety and service condition of road pavement can be maintained only if effective road drainage exists. Water on the pavement can reduce skid resistance, can interrupt traffic, limit visibility due to splash and spray, increase potential for hydroplaning, and cause difficulty in driving of vehicle. Due to slow precipitation of water and pooling on the carriageway resulting in restricted width and carrying capacity, inturn leading to congestion and slow movement of traffic after showers.

The total road drainage composes of surface drainage, flow in the drains and capacity of inlets. The design of these elements depends on storm frequency and allowable spread of storm water on pavement surface. This chapter elaborates on guidance to these elements.

3.2 Surface Drainage

The rain water travels as unsteady non uniform sheet flow from middle of pavement to the edge of pavement. Factors influencing the depth of water on pavement are the flow of path length, surface texture, surface slope and rainfall intensity. Design guidelines on existing parameters for the following drainage elements are essential.

3.2.1 *Longitudinal gradient of pavement*

3.2.2 *Transverse gradient of pavement*

3.2.3 *Hydroplaning*

3.2.4 *Shoulder drainage & footpath drainage*

3.2.5 *Road side and median drainage*

3.2.6 *Bridge decks*

3.2.7 *Median barriers*

3.2.1 *Longitudinal gradient of pavement*

The minimum longitudinal gradient is governed by drainage considerations of pavement. This minimum longitudinal gradient is more important for a kerbed pavement than for an unkerbed pavement. On unkerbed pavements near level longitudinal gradients may not be objectionable, when the pavement has sufficient camber to drain rain water laterally. For effective and efficient internal drainage of pavement layers, especially for granular materials, at least a minimum gradient is essential. Also, in cut sections and medians, a slight gradient is desirable to facilitate the removal of water. Desirable longitudinal gradients shall not be less than 0.50 percent for pavements for satisfactory drainage.

A minimum longitudinal gradient of 0.30 percent is necessary to facilitate flow of water in side drains. With outlets example like bridges, culverts, ponds, nallas are provided at required interval to restrict the depth of drains.

3.2.2 *Transverse gradient of pavement/camber*

The transverse gradients are compromise between the need for reasonably steep gradients for drainage and relatively flat gradients for driver comfort and safety. For quick dispersal of precipitation on the road surface, it would be necessary that water has to travel least distance through reasonably steep cross slope. However from the consideration of comfort to traffic, steep cross slope is objectionable. As such, a judicious balance is required to be kept between the two requirements. Cross slopes of 2 percent have little effect on driver comfort in steering or on friction for vehicle stability. The use of cross slope exceeding 2 percent on pavements with a central crown line is not desirable. In areas of intense rainfall, a steeper cross slope of 2.5 percent may be adopted for effective drainage. However in surfaces like graveled or WBM cross slope ranging between 2.5 to 3.0 percent can be considered.

For urban roads having divided carriage way, the camber is unidirectional away from the median. A few typical cross sections are shown in **Fig. 3.1 & 3.2 (a) (b) (c) & (d).**

In case of super elevated sections, either gap in the central verge with suitable adjustments in the levels of the two carriageways or in extreme cases, central drainage arrangement is resorted to. Schematic arrangement is shown in **Fig. 3.1**.

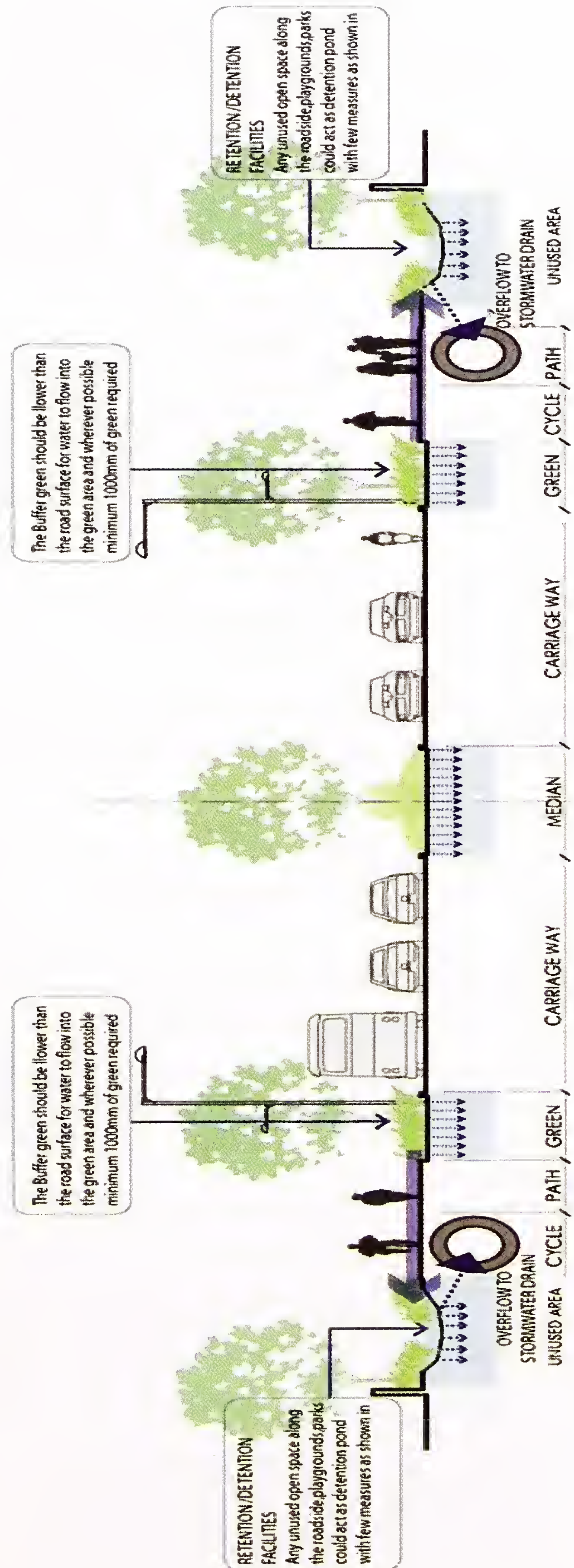
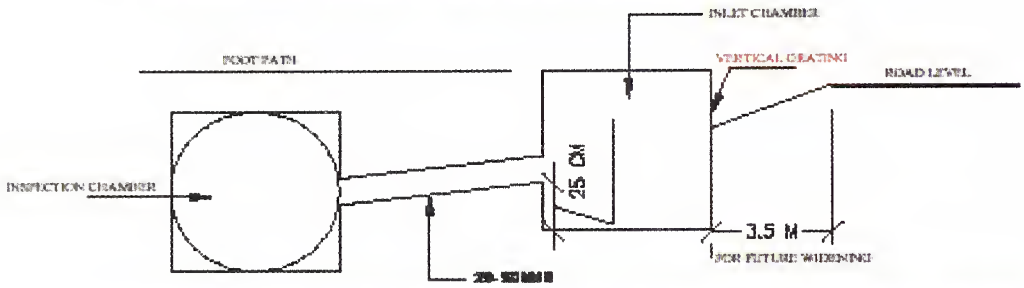
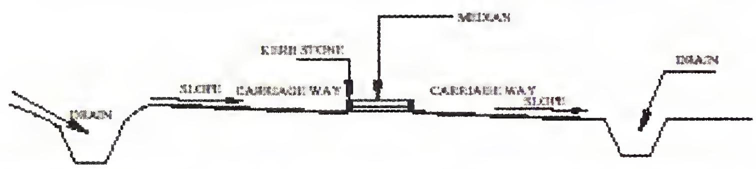

RETENTION/DETENTION FACILITIES
Any unused open space along the roadside,playgrounds,parks could act as detention pond with few measures as shown in
The Buffer green should be llower than the road surface for water to flow into the green area and wherever possible minimum 1000mm of green required
UNUSED AREA
OVERFLOW TO STORMWATER DRAIN
CYCLE
PATH
GREEN
CARRIAGE WAY
MEDIAN
CARRIAGE WAY
GREEN
CYCLE
PATH
OVERFLOW TO STORMWATER DRAIN
UNUSED AREA
The Buffer green should be llower than the road surface for water to flow into the green area and wherever possible minimum 1000mm of green required
RETENTION/DETENTION FACILITIES
Any unused open space along the roadside,playgrounds,parks could act as detention pond with few measures as shown in

Fig. 3.1

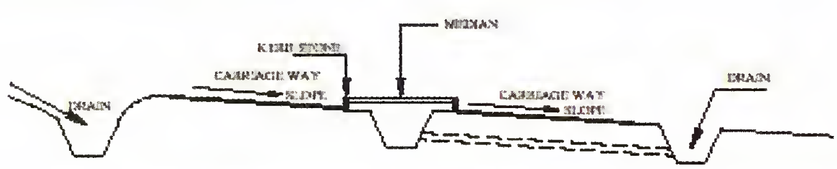
a) SCHEMATIC ARRANGEMENT IN STRAIGHT REACH



b) SCHEMATIC ARRANGEMENT OF CATCHPIT AND COVERED DRAIN



C) SCHEMATIC ARRANGEMENT AT SUPER ELEVATION THE OPENNING IN THE MEDIAN SHOULD BE (PAVED) 60CM WIDE SPACED AT 2 TO 3M



d) SCHEMATIC ARRANGEMENT AT SUPER ELEVATION WITH CENTRAL DRAINAGE ARRAMGEMENT

Fig. 3.2 Schematic Arrangement for Water Collection and Disposal (Contd.)

Slope of 1 in 40 & 1 in 50 respectively for flexible and rigid pavement

Fig. 3.3 (a) & (b) explains the method of storm water management for retrofitting of existing road section for efficient drainage of storm water

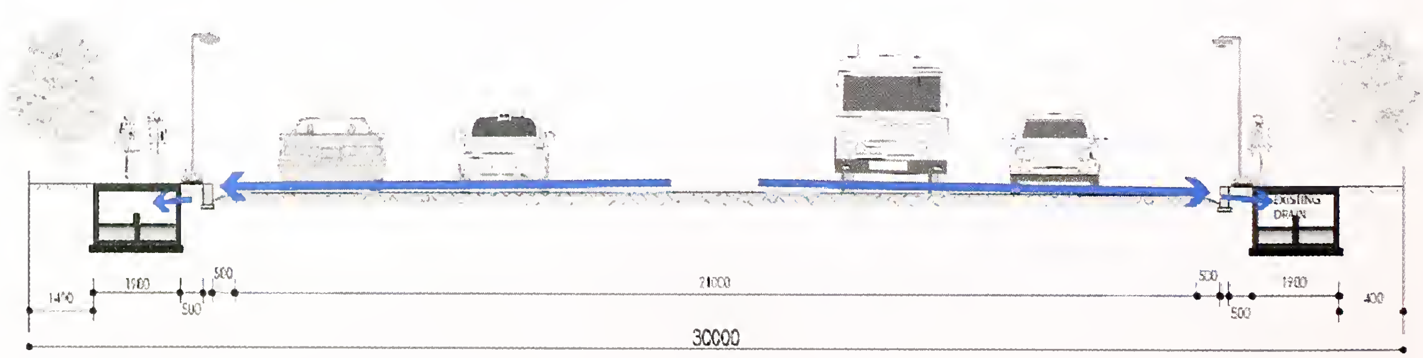


Fig. 3.3 (a) Schematic Road Section for Retrofit of Existing Road

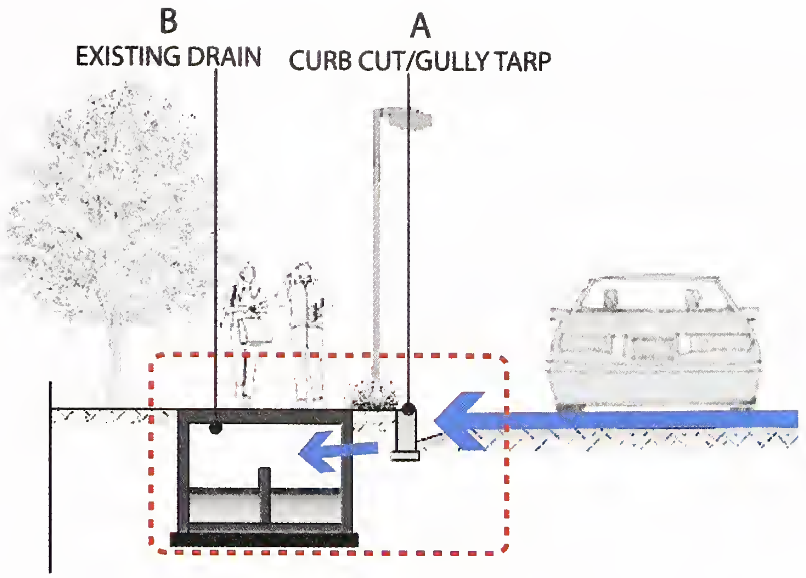


Fig. 3.3 (b)

a) Water from road should get directed towards the road edge and should enter the storm water drain through kerb opening

b) Covered drain at location B may be Hume pipe/cast in situ/precast channel.

Deeper Kerb with options are shown in the **Fig. 3.4, 3.5 & 3.6** and facilitate quick exit of water from pavement to drain. A typical cross section of storm water drain in new road is shown in **Fig. 3.7,** a general arrangement of gully chamber and drain is shown in **Fig. 3.8**.

Different kerb cut options are illustrated below

Option 1

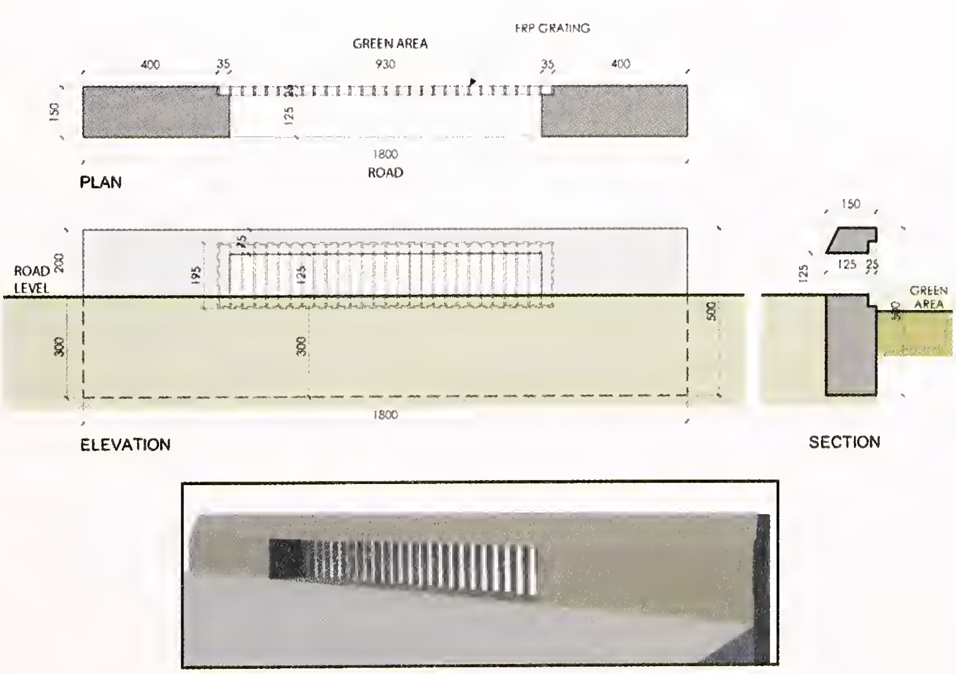
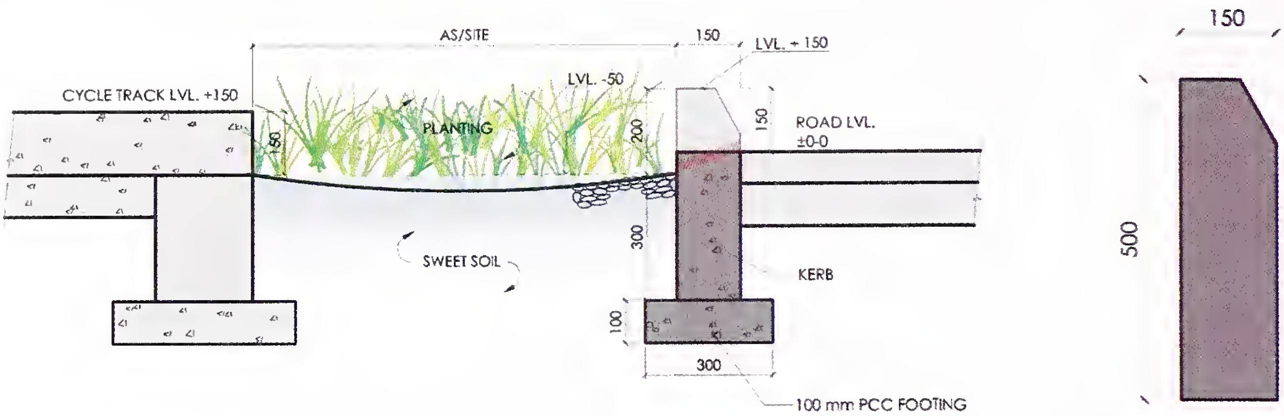


Fig. 3.4

Option 2

The Kerb depth would be more than conventional kerb depth & green area level should be lower than adjacent road level.



The median walls shall be taken for considerable depth upto subgrade level of road so that water does not seep into base or sub base layers of pavements.

Option 3

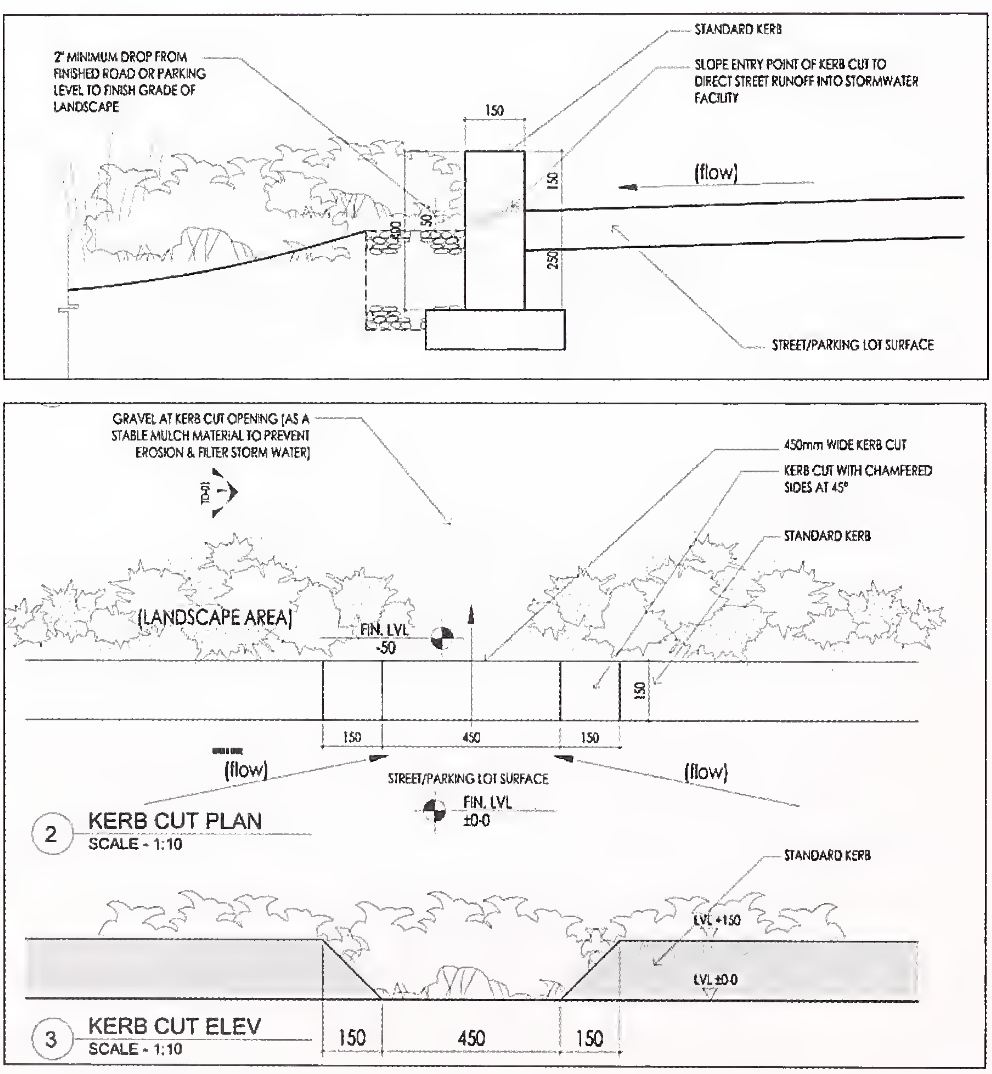
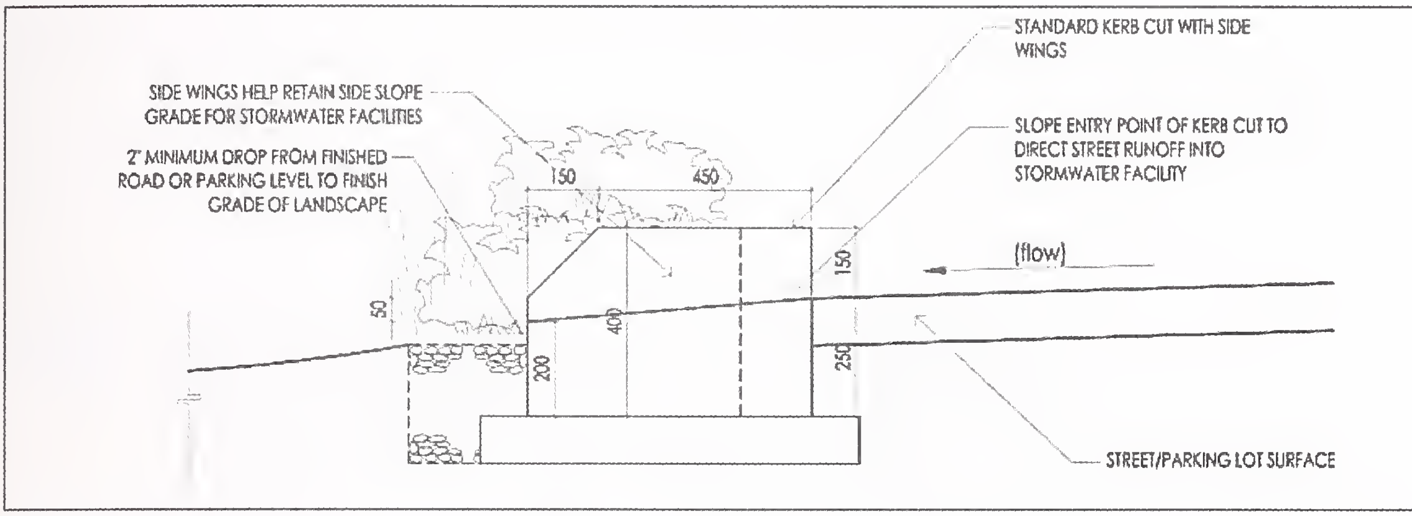


Fig. 3.5 Typical Kerb Cut

Option 04:



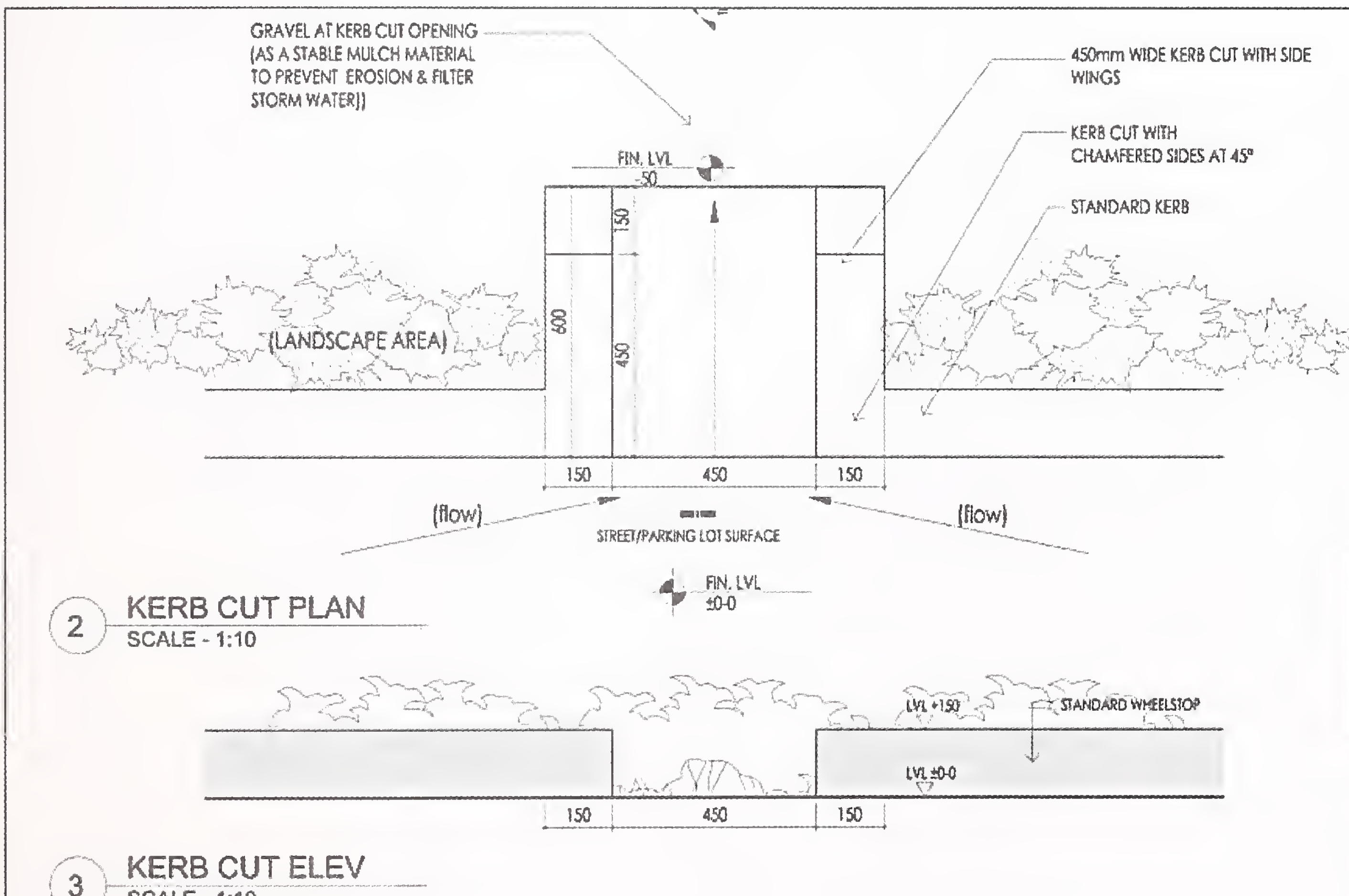
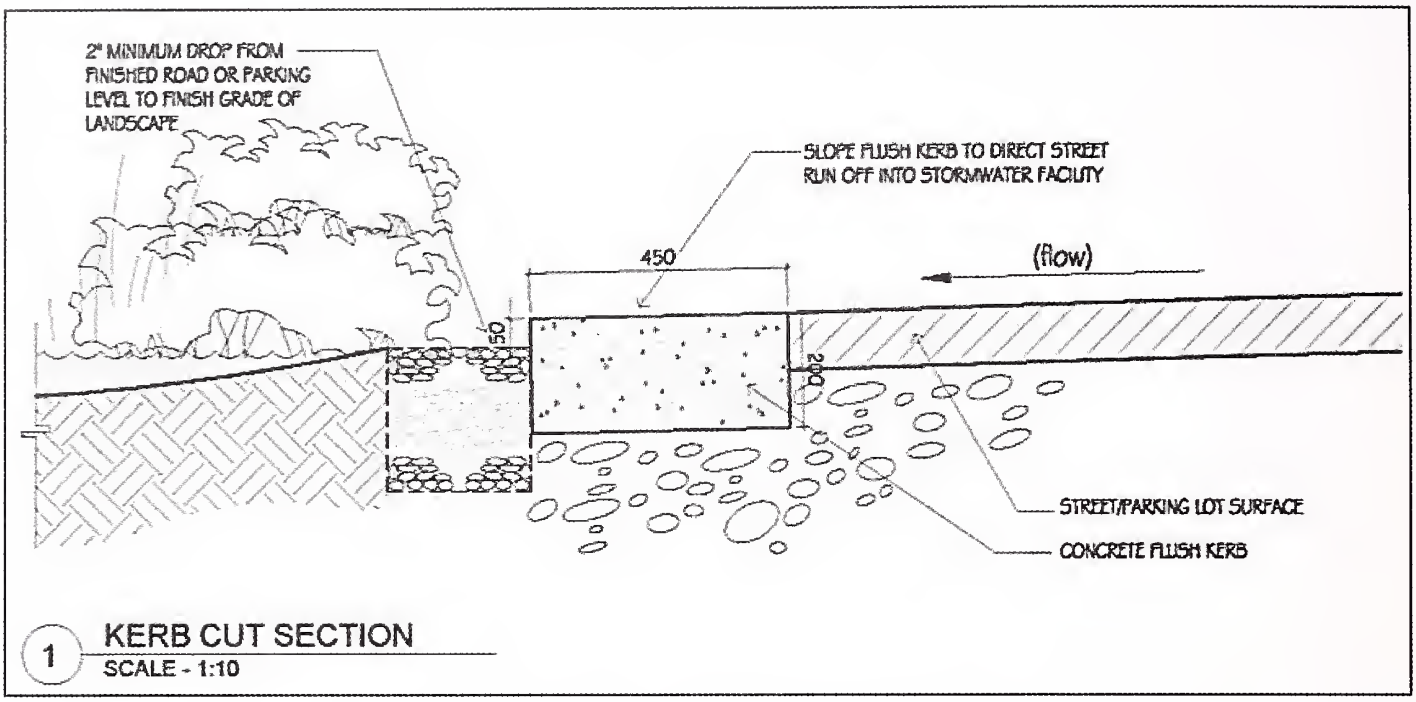


Fig. 3.6 Typical Kerb Cut with Side Wings

Option 05:



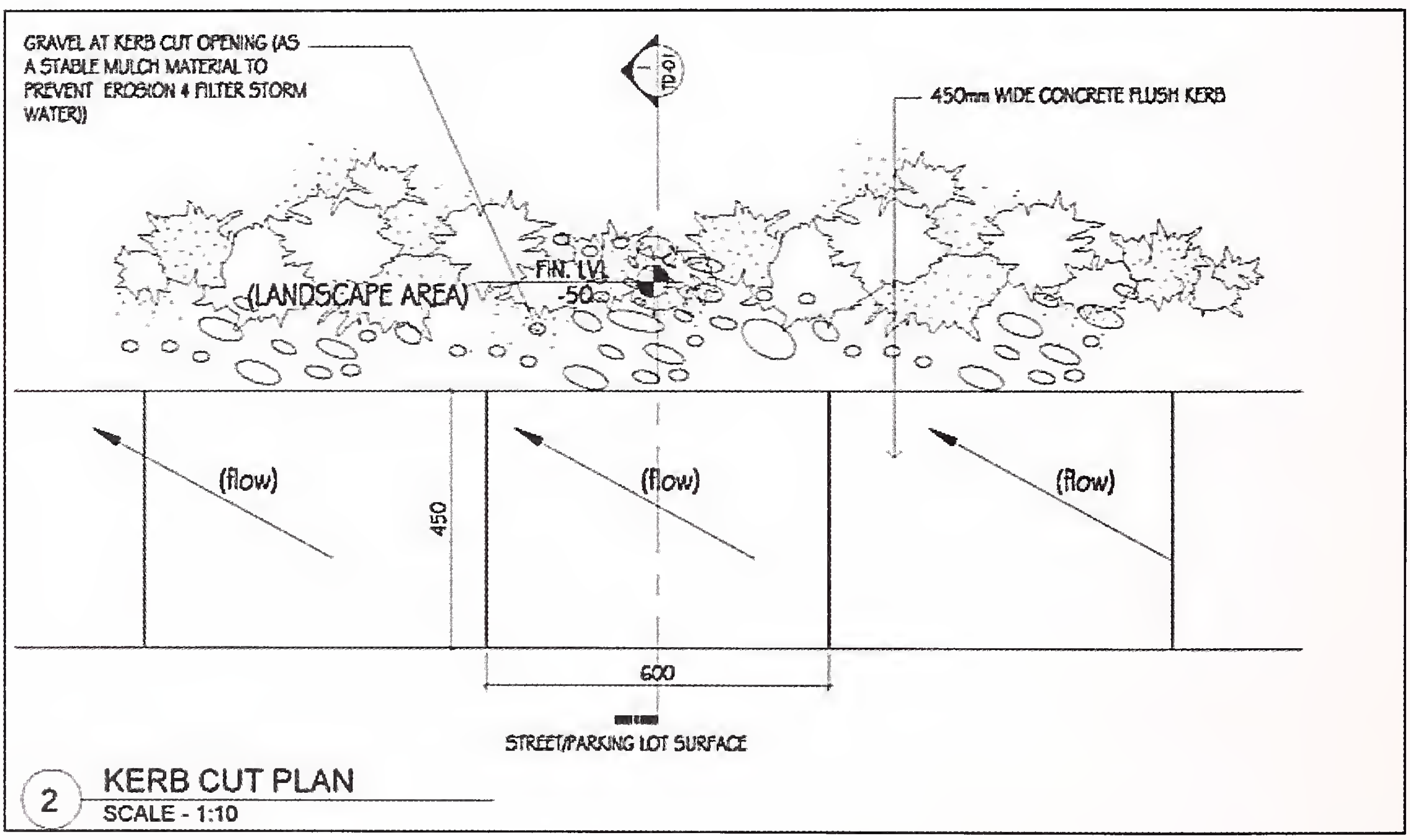


Fig. 3.7 Typical Flush Kerb Cut

The typical cross section of storm water drain in new road

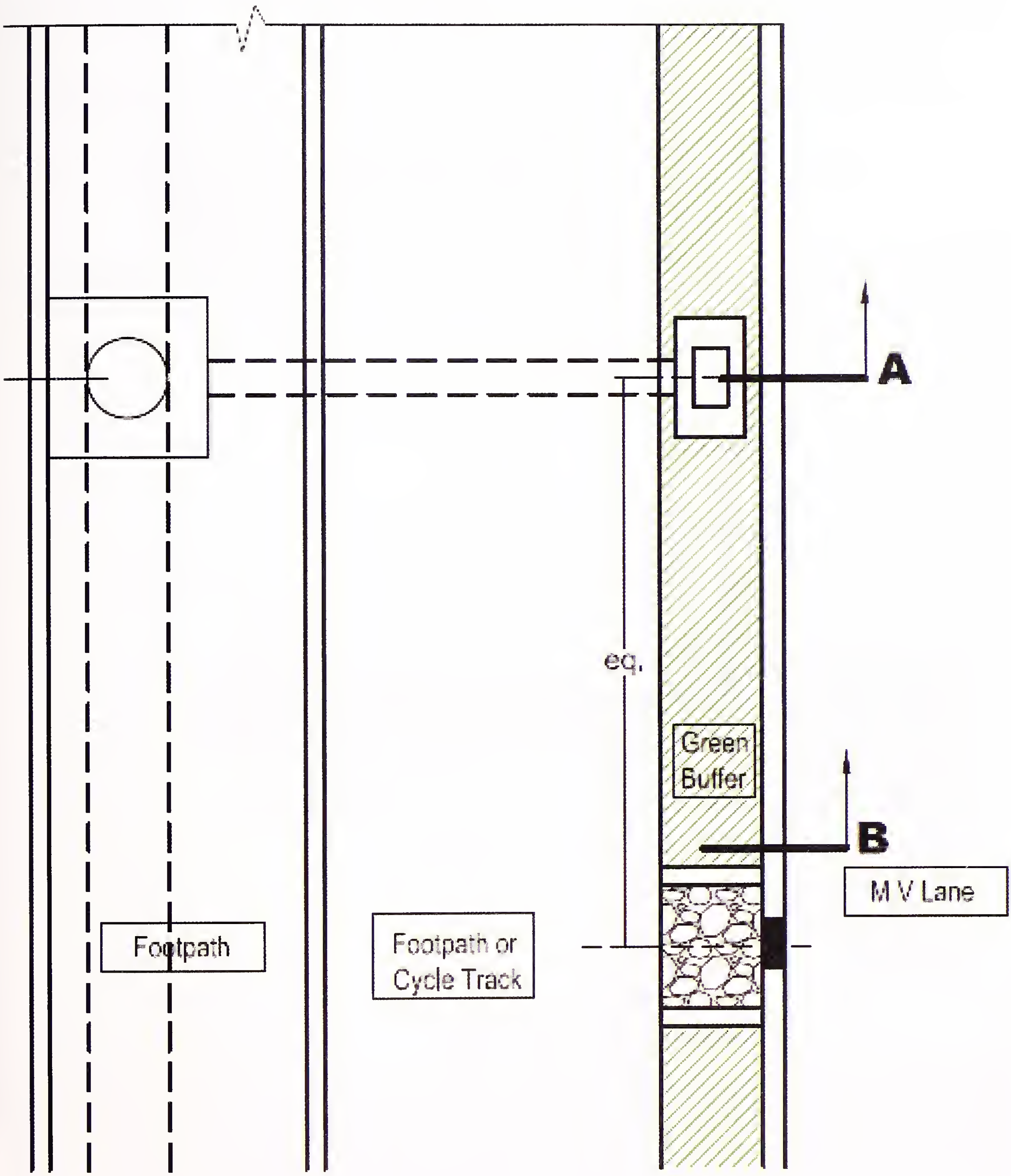
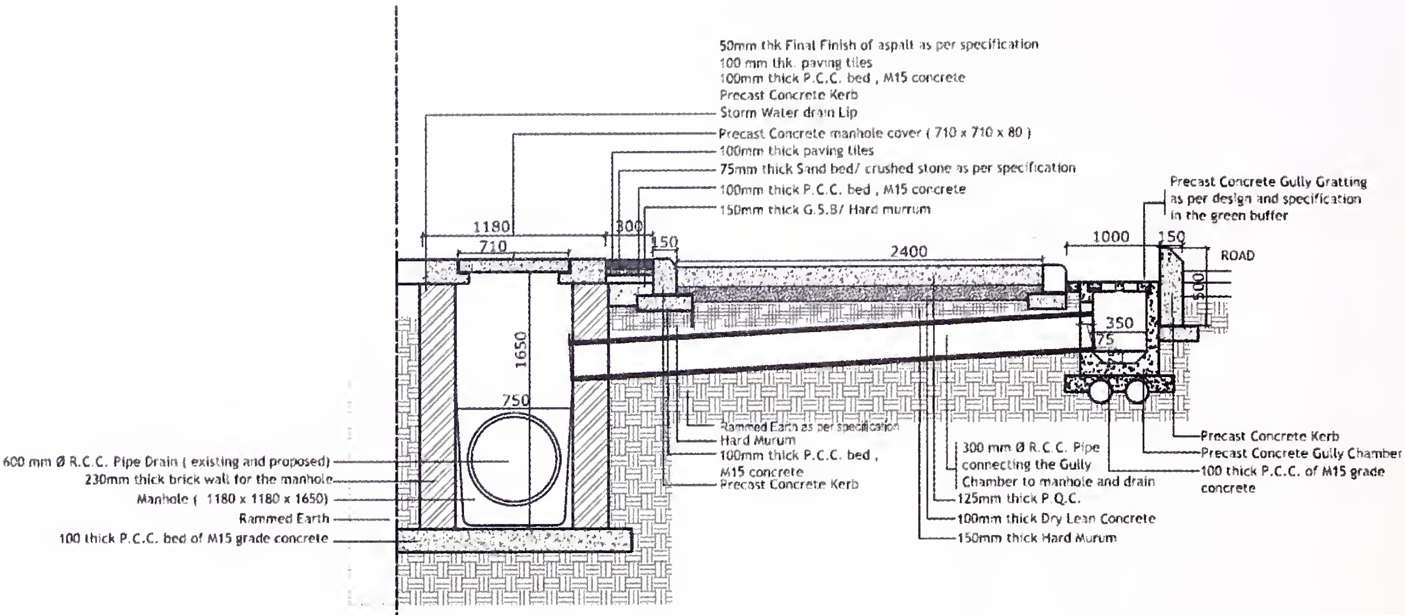
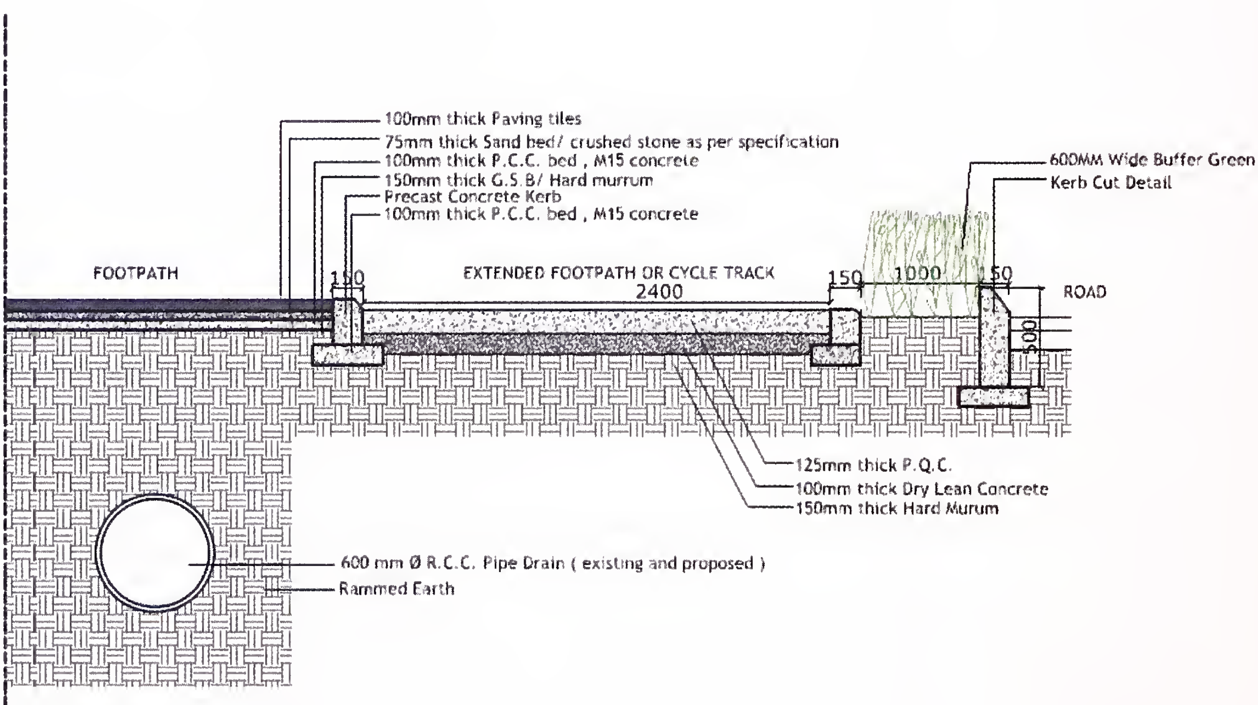


Fig. 3.8



SECTION AA



SECTION BB

Fig. 3.8 a

SECTION AA Showing connection from gully trap to storm water pipe drain. SECTION BB Showing the positioning of curb cut which will allow the storm water from road to get diverted to the green buffer.

The green buffer should be mandated as minimum 600 mm streets < 24 m ROW. In case of streets > 24 m ROW it should not be less than 1000 mm. The green should always be lower than the road surface.

If there is less space on roadside, water can be taken through drain channel to nearby large green area or other retention/detention facility or harvesting system as shown in **Fig. 3.9.1, 3.9.2 and 3.9.3**.

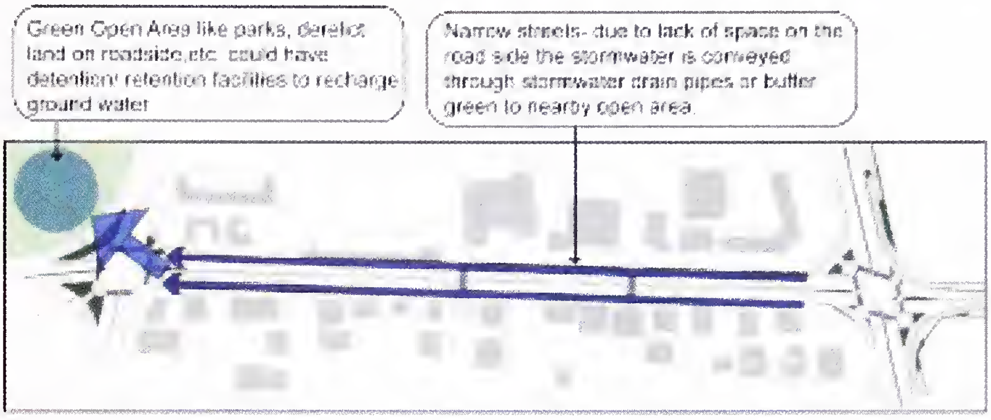
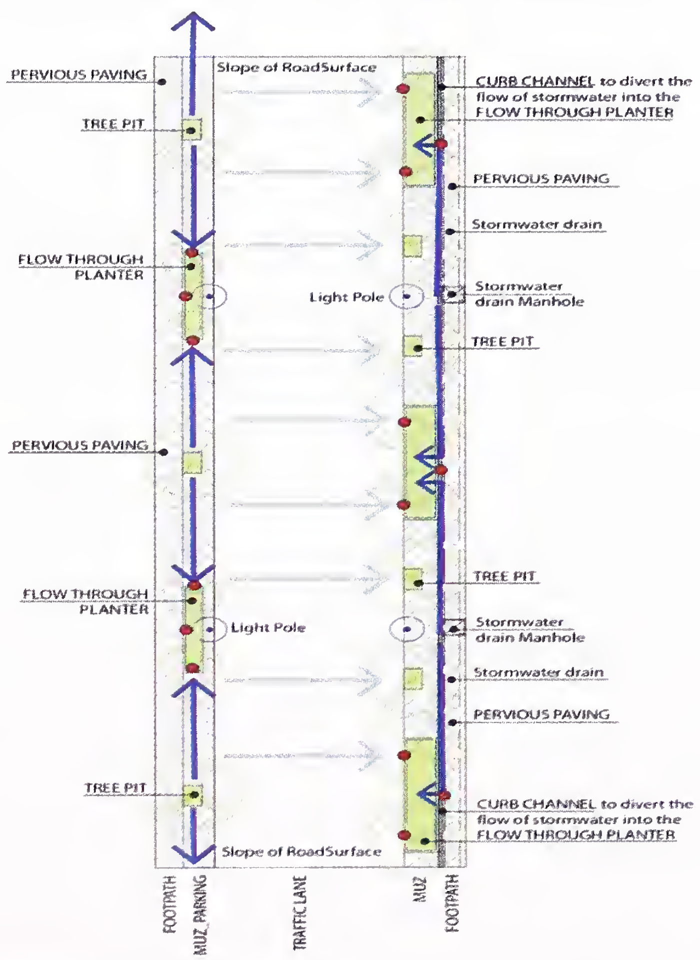


Fig. 3.9.1

ALTERNATIVE FOR SWM FOR NARROW STREETS



Width of FLOW THROUGH PLANTER provided in MUZ zone will vary as per space availability , in any case width should not be less than 1000mm clear.

● CURB CUT POSITION to allow stormwater to flow in the FLOW THROUGH PLANTER

P.S.NOTE: All the overflow will be directed to the stormwater drain on the RHS of the road running under the footpath.

SCHEMATIC ARRANGMENT OF STORMWATER PRACTICES ON 18 mts TO 24 mts ROAD WIDTH

Fig. 3.9.2 Schematic Arrangement of Storm Water Practices on 18 M to 24 M Road Width

Fig. 3.9.3 shows GENERAL ARRANGEMENT OF GULLY CHAMBER AND DRAIN

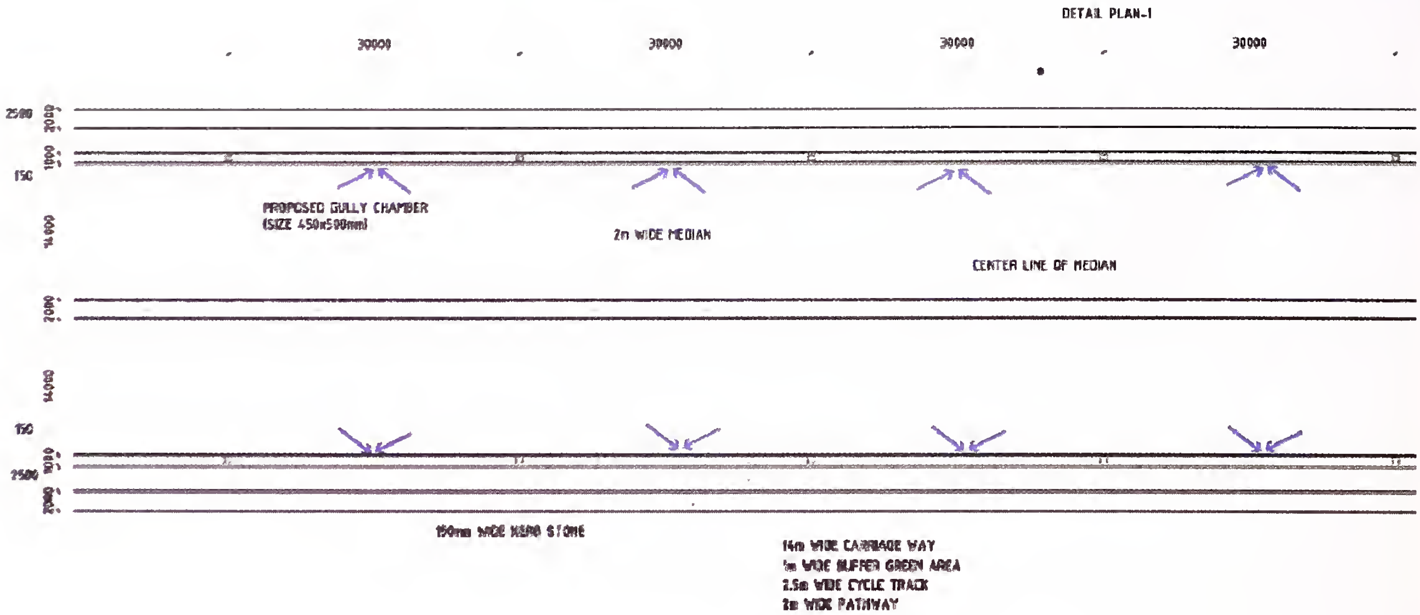


Fig. 3.9.3

When the road is in gradient, the flow of rain water is governed by the resultant slope produced by longitudinal and cross slope. In such case, in order that water travels the least distance on road surface (more the distance more is the quantity of sheet flow causing hydroplaning), the camber should be 0.7 of the longitudinal gradient or the camber values specified in the following table for a particular road surface whichever is higher. In other words, on steep gradients on long length of road, the camber should be increased to get satisfactory drainage conditions.

Special care is also required in detailing the valley curves so that such locations do not collect water.

IRC:86 "Geometric Design Standards for Urban Roads in Plains" recommends that camber or cross slope on straight sections of roads as given in **Table 3.1**.

Table 3.1 : Cross Fall/Camber Values for Different Road Surface Types

Surface Type	Cross fall/Camber
Graveled or WBM surface	2.5 to 3 percent
Thin bituminous surfacing	2 to 2.5 percent
High type bituminous surfacing or cement concrete surfacing	1.7 to 2 percent

Note : Higher value of camber should be adopted in areas with high intensity of rainfall and where ponding is expected due to any reason. Steeper camber should also be provided on kerbed pavements to minimize the spread of surface water.

Additional guidelines to transverse gradients are suggested as below:

i) Although not widely encouraged, inside lanes can be sloped towards the median if conditions warrant.

ii) Median areas should not be drained across travel lanes as far as possible.

iii) The number of length of the flat pavement sections in cross slope transition areas shall be minimized. Consideration shall be given to increasing cross slopes in sag vertical curves, cross vertical curves and in sections of flat longitudinal grades.

iv) Shoulders shall be sloped to drain away from the pavement, except with raised, narrow medians and super elevations.

3.2.3 *Hydroplaning*

When water level increases on the road, the drainage capacity of the tyre tread pattern and pavement surface is exceeded and the water begins to build up in front of tyre, the occurrence of this phenomenon is called hydroplaning. The potential for hydroplaning increases, when the depth of water flowing over a roadway surface increases. When a rolling tyre encounters a film of water on the roadway, the water is channeled through the tyre tread pattern and through the surface roughness of the pavement. As the water builds up, a water wedge is created and this wedge produces a hydrodynamic force which can lift the tyre off the pavement surface. This is considered as full dynamic hydroplaning and since water offers little shear resistance, the tyre losses in tractive ability resulting in loss of control of the vehicle. There is also loss of stability of the vehicle. Hydroplaning can occur at speeds of 80-90 kmph with a water depth of 2 mm.

Hydroplaning is a function of water depth, roadway geometrics, vehicle speed, tread depth, tyre inflation pressure and conditions of pavement surface. The driver is responsible for using caution and good judgment when driving in wet conditions similar to as when driving on snow. In problematic areas, hydroplaning may be reduced by the following:

i) Designing the highway geometrics to reduce the drainage path length of the water flowing over the pavement, which will prevent build up of flow.

ii) Increasing the pavement surface texture depth, by such methods as grooving of cement concrete. An increase of pavement surface texture will increase the drainage capacity at the tyre – pavement interface.

iii) Certain developed countries are adopting porous bituminous layer by which water gets percolated from the surface and drains out from sides. This could be tried in our country with effective supervision during lying. See also figure in Chapter-10, 10.1(vi) (b).

iv) The effective use of drainage structures along the roadway will reduce the thickness of film of water while flowing over the pavement and reduce the hydroplaning potential of the roadway surface.

3.2.4 *Roadside gutter and inlets*

For shoulders along unkerbed pavement the cross fall should be at least 0.5 percent steeper than that of the pavement subject to the minimum values given below:

WBM surface	3 percent
Gravel surface	4 percent
Earth surface	5 percent

In addition, it is necessary that shoulders are not higher than adjoining pavement surface to prevent pooling of water at the edge of carriage way and for quick drainage.

For paved footpaths a cross-fall of 3 to 4 percent should be adopted sloping away from the carriage way. For verges and unpaved areas cross-fall should be 4 to 6 percent.

Precipitation from the road surface flows towards outer edge of carriageway (except where central drainage arrangement has been provided) in to shoulder drain where kerb and footpaths are provided. The roadside gutter and inlets shall be a minimum of 600 mm wide with internal smooth finish and shall have a minimum transverse slope of 1 in 6. The longitudinal slope of roadside gutter and inlets is guided by the road gradient. In reaches where there is no longitudinal gradient in the road, roadside gutter and inlets shall slope away from kerb inlet or bell mouths. The roadside gutter and inlets discharge its flow in to road side drains. All due care shall be taken to geometrically design the drain for its easy maintenance. The spacing may require to be placed depending upon the longitudinal gradient of the road. The inlets could be grated kerb, combined grated kerb, sag point inlet with outflanking inlets

The spacing of inlets depends on condition of road surface size and type of inlet and rainfall. They shall be provided at closer intervals near junctions and valley curves; however maximum spacing shall not be more than 30 m.

The road side drains can be constructed out of any locally available materials like bricks, size stones, solid blocks or RCC (where slender walls are required and combined utility ducts can be provided), wee holes at regular intervals to cut down the water table and drain the subgrade water are to be provided.

The alignment of roadside gutter and inlets underneath the sidewalk shall be in the direction of flow of water during storm for efficient discharge as shown in **Fig. 3.2.4 (a)**.

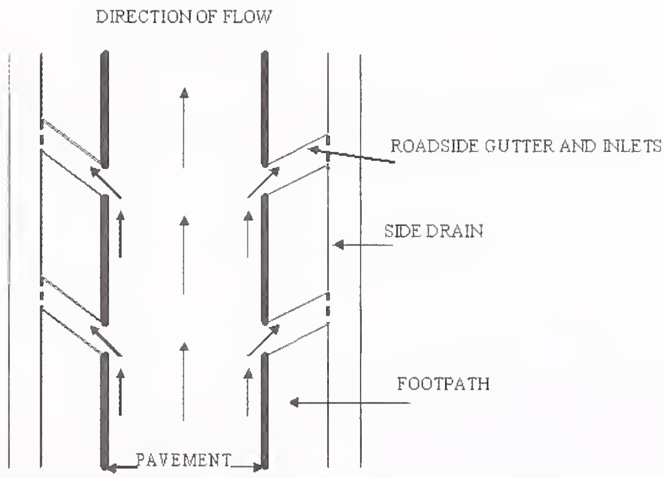


Fig. 3.2.4 (a) Inclination of Roadside Gutter and Inlets with Respect of Flow in Pavement

The shoulder drains shall generally be spaced at longer intervals upto 50 m in level grounds and at closer intervals upon 5 m in saddle areas and junctions. The shoulder drains in high intensity traffic areas shall be upto 3 m in regions like Mumbai. The shoulder drains can also be of NP3 pipes of circular, horse shoe, elliptical shapes

The median walls shall be taken for considerable depth upto subgrade level of road so that water does not seep into base or sub base layers of pavements.

In locations where carriageway slopes towards median, as may be the case where road is in curve, necessary openings shall be provided in the median for smooth passage of water from one lane to other and to onwards side drain. The determination of median crossings for drainage requires good engineering judgment. These crossings are governed by hydraulic as well as non-hydraulic considerations.

In curves, the median acts as an obstruction to flow of storm water towards inside of curve leading to flooding of the outer carriageway. A median opening shall be provided from outer to inner edge of median. See **Fig. 3.2.4 (a) & Fig. 3.2.4 (b)**

The provision of median openings at super elevation and curves in divided carriageway shall be for and upto two lanes is shown in **Fig. 3.2.4 (b)** and **Photo 3.2.4 (a).** When each carriageway is three lane or more, then a drain shall be introduced below the median and inturn connected to lower level drain by a minimum 600mm dia NP3 pipes. See **Fig. 3.2.4 (c)**.

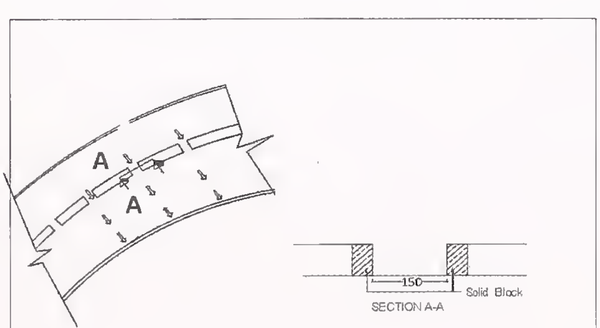


Fig. 3.2.4 (b) Median Opening upto Two Lane Carriageway on each Side

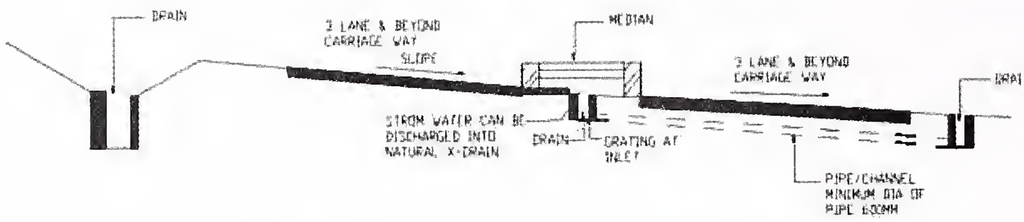


Fig. 3.2.4 (c) Drainage Arrangement at Medians for Three Lane and Beyond on each Carriageway

Photo 3.2.4 (a) Median Opening's

3.2.5 *Bridge deck drainage*

Bridge deck drainage will be relatively less efficient than road way drainage due to flatter cross slopes, gutters collect large amount of debris and drainage spouts are less hydraulically efficient and more easily clogged by silt and debris. Because of the difficulties in providing for and maintaining adequate deck draining systems, side drain flow from road ways shall be intercepted before it reaches the bridge. For similar reasons, zero gradients and sag vertical curves shall be avoided on bridges. Additionally, runoff from bridge decks shall be collected immediately through drainage sprouts with gratings after it flows into the subsequent pavement section where larger grates and inlet structures limiting to shy distance shall cater for effective end point drainage. Splashing of collected water on vehicles moving on the bridge will result in reduced visibility and cause accidents. Each pier shall have a drainage disposal pipe designed for the area of disposal for immediate discharge of rain water from bridge deck.

3.2.6 *Drainage of high embankment*

In high embankments and approaches to bridges, if the water is allowed to leave the carriageway at undefined spots, it may cause serious damages to the embankment and eventually undermines the pavement. In each location rain water is collected in small manageable quantities through longitudinal kerb channel and brought down through stepped chutes without damage. The chutes may be lined with cement concrete on stable supports and may be located at 10 to 15 m intervals depending upon the rainfall and width of carriageway. Stepped outfall may be used in place of chutes. Typical drainage arrangement and typical chute sections and energy potential construction of steps or simple energy dissipation structures may need to be provided and the same is shown in **Fig. 3.2.6.** For protection of slopes between chutes. IRC:SP:42 "Guidelines on Road Drainages".

The recent trend of providing earth reinforced walls instead of retaining walls to approaches of bridges and flyovers has eliminated the high earthen, wide embankment at base and have efficient drainage system. The storm water reaches the approaches which required to be provided with catch drain as in case of subways. Arrangement shown in **Fig. 9.3 (a)** in **Chapter-9.**

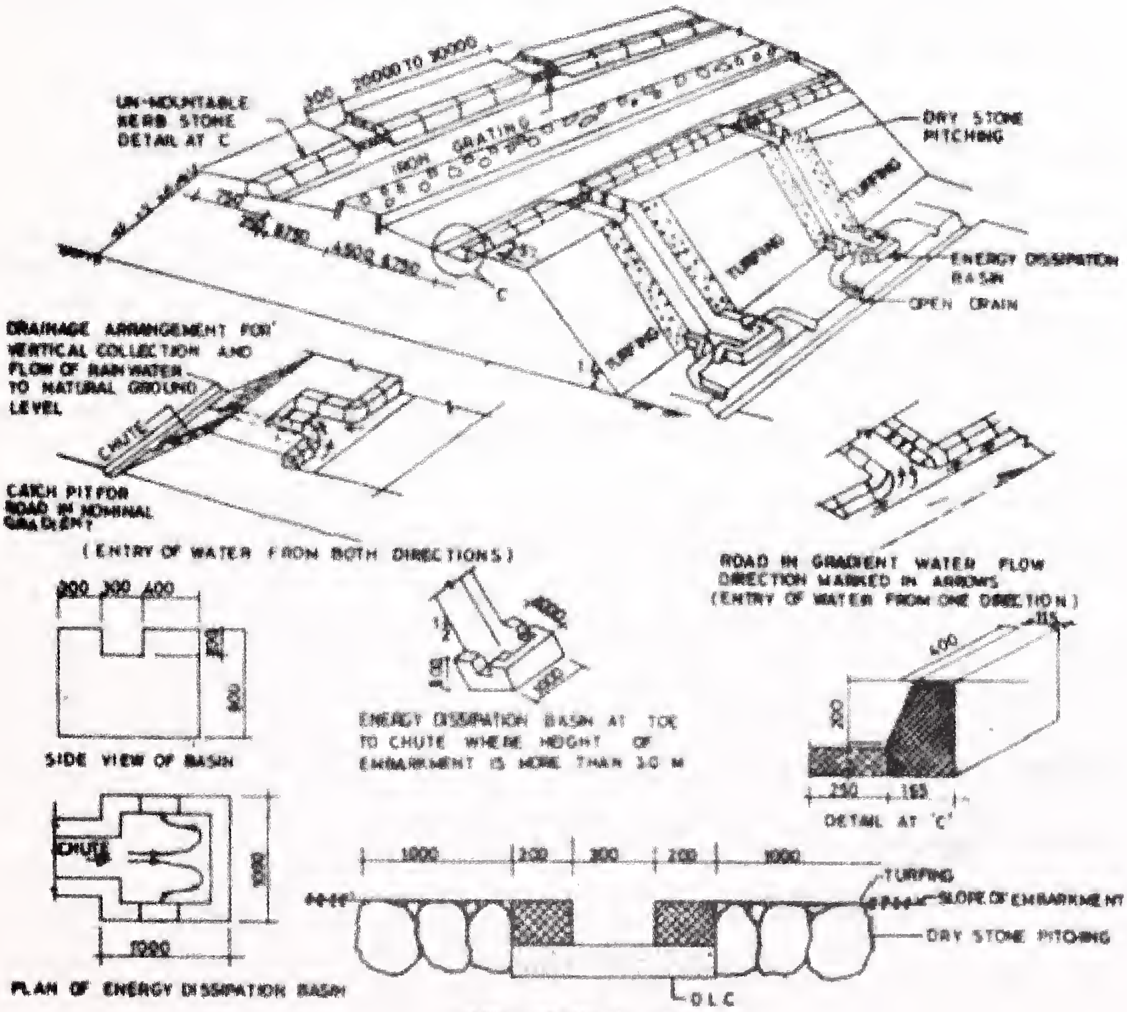
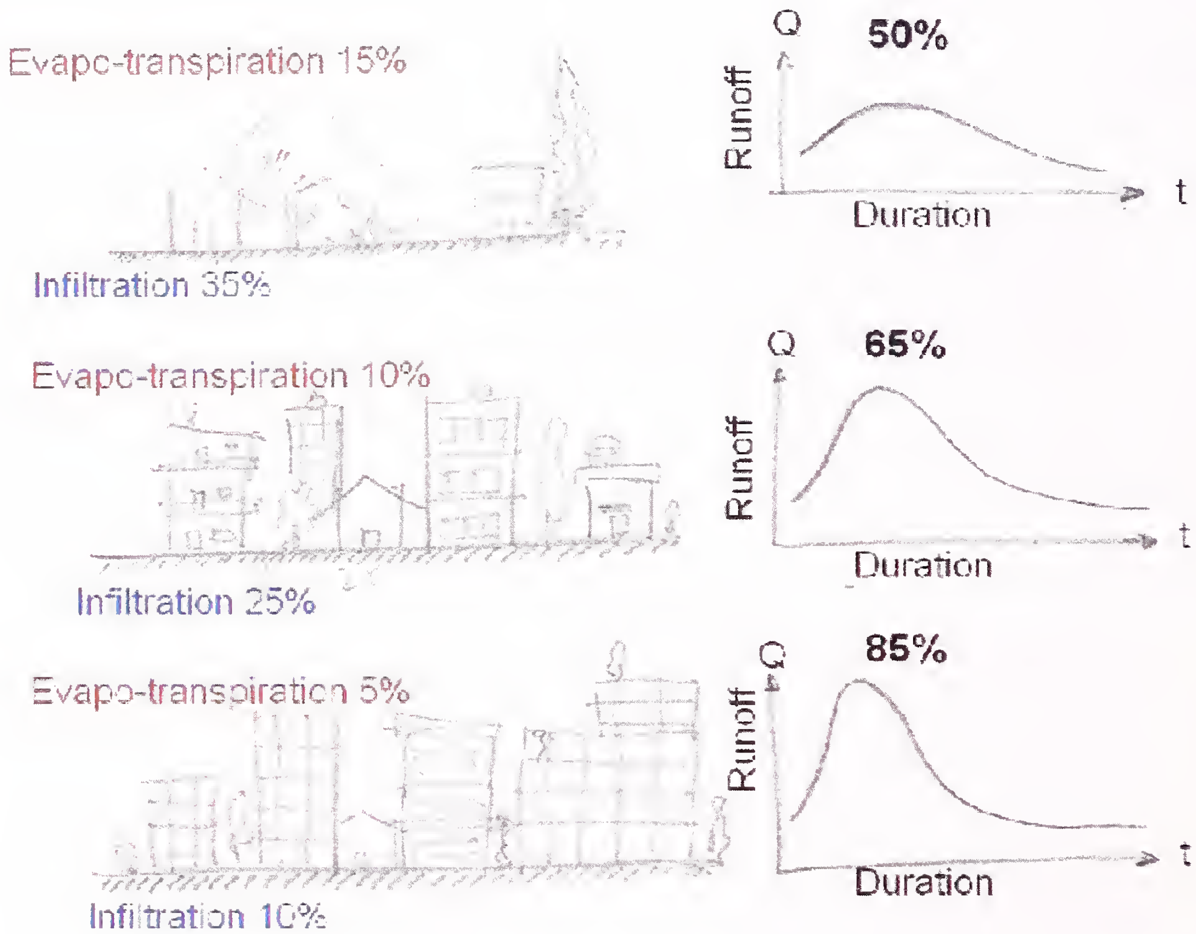


Fig. 3.2.6 Perspective view of Standard Dual Carriageway Pavement with Paved shoulder Showing Drainage Arrangement for Collection and Flow of Surface Water to Natural Ground Level

4 STORM WATER MANAGEMENT PRACTICES

In the present scenario of depletion of ground water level, consequently increasing alarming levels of fluorine and other similar contaminants has endangered seriously the health of public.



Relationship between Impervisioness and Surface Runoff

The urbanization has resulted in all types of construction activities primarily paved roads, lined drains, which were earlier acting as pervious natural surface. Due to the reduction of infiltration owing to urbanization causing increased volume of runoff, surfaces are also smooth there by allowing more rapid drainage and ground water storage is usually reduced. The natural drainage systems are also replaced by lined channels, storm water drains and kerb and gutter systems. This system produces an increase in runoff volume and peak discharge, as well as reduction in time to reach peak runoff.

4.1 Design Strategies for Stormwater Drainage System

Storm water can be managed by adopting following measures

There are three main principles to follow sustainable storm water management:

1) Disconnecting the flow of storm water from the conventional pipe system and using all possible alternate areas for recharge.

In the conventional system as shown below, there is no opportunity for storm water to infiltrate into the ground other than in primary drain.

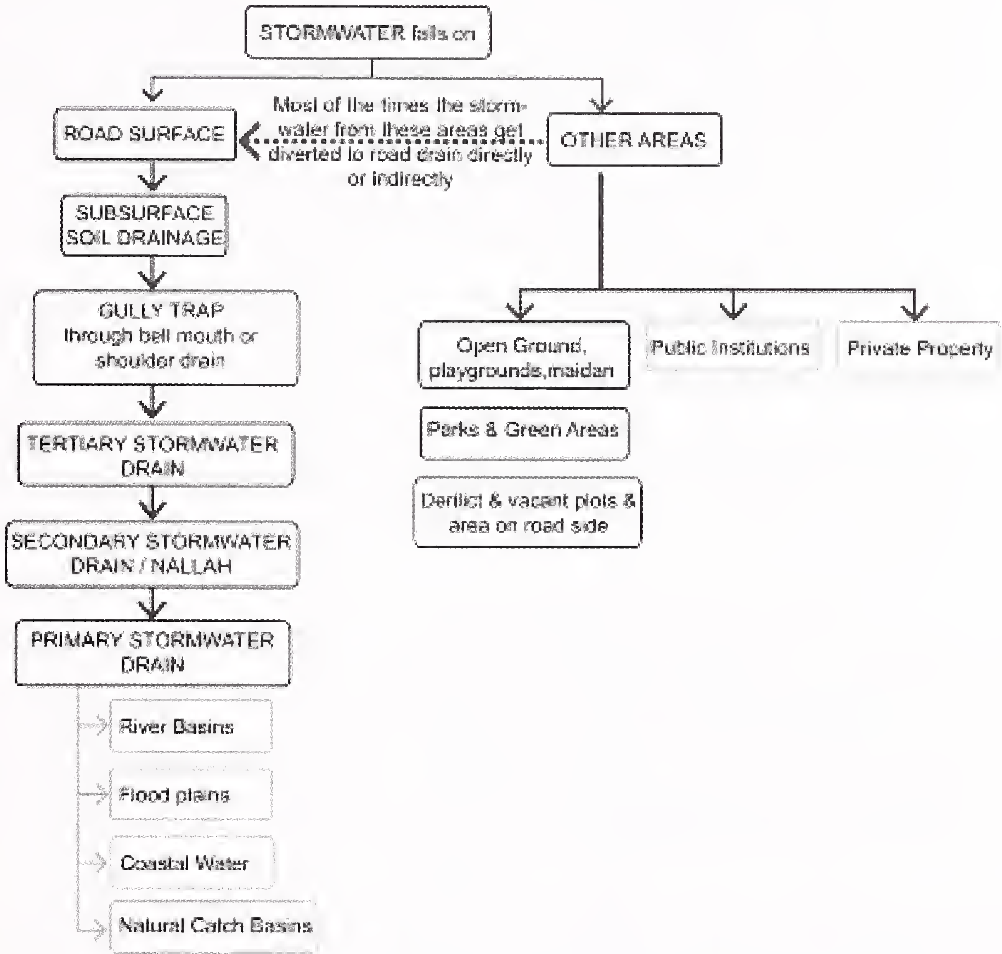
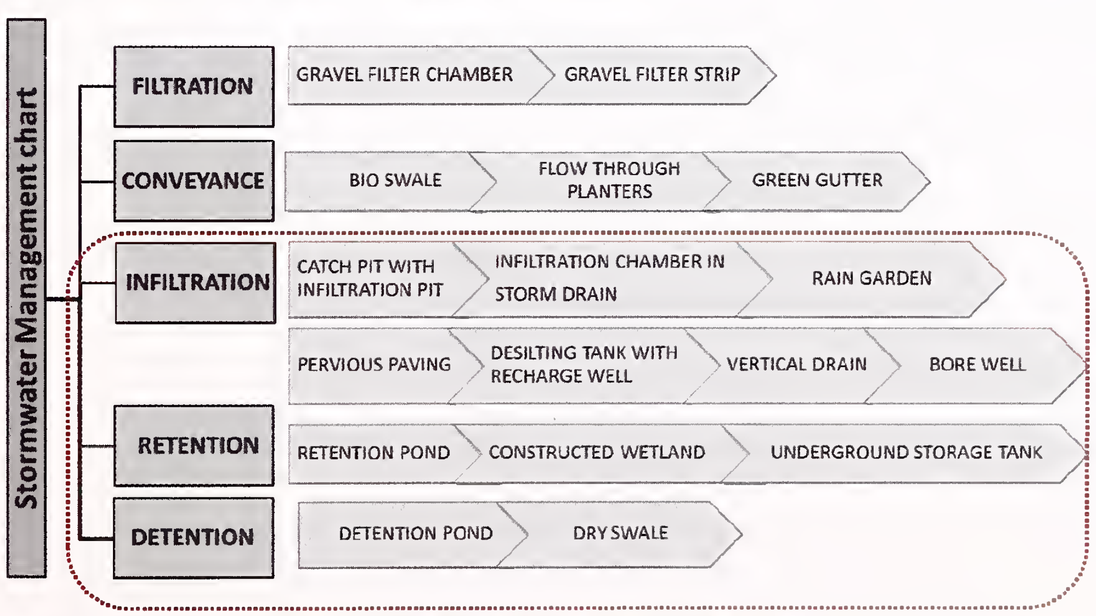


Fig. 4.1 Conventional Method of Storm water Management

STORM WATER MANAGEMENT CHART



For details of Infiltration, retention & detention please refer chapter 10.

4.1.1 *Filtration*

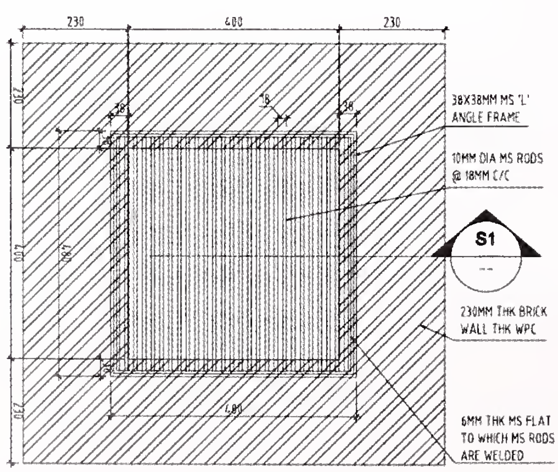
- Prevents sediments and other materials from reaching and clogging downstream facilities.
- The slow movement of runoff through vegetation or gravel provides an opportunity for sediments and particulates to be filtered and degraded through biological activity.
- In draining soils, the filters also provides an opportunity for storm water infiltration, which further removes pollutants and reduces runoff volumes.
- These are especially applicable to parking lots and along highways as they can be sloped into linear grass or rock swales to collect and treat runoff from pavement surfaces. Adjacent pavement level should be slightly higher than the filtration area.
- Filtration can include rock and vegetated swales, filter strips or buffers, sand filters.

Infiltration

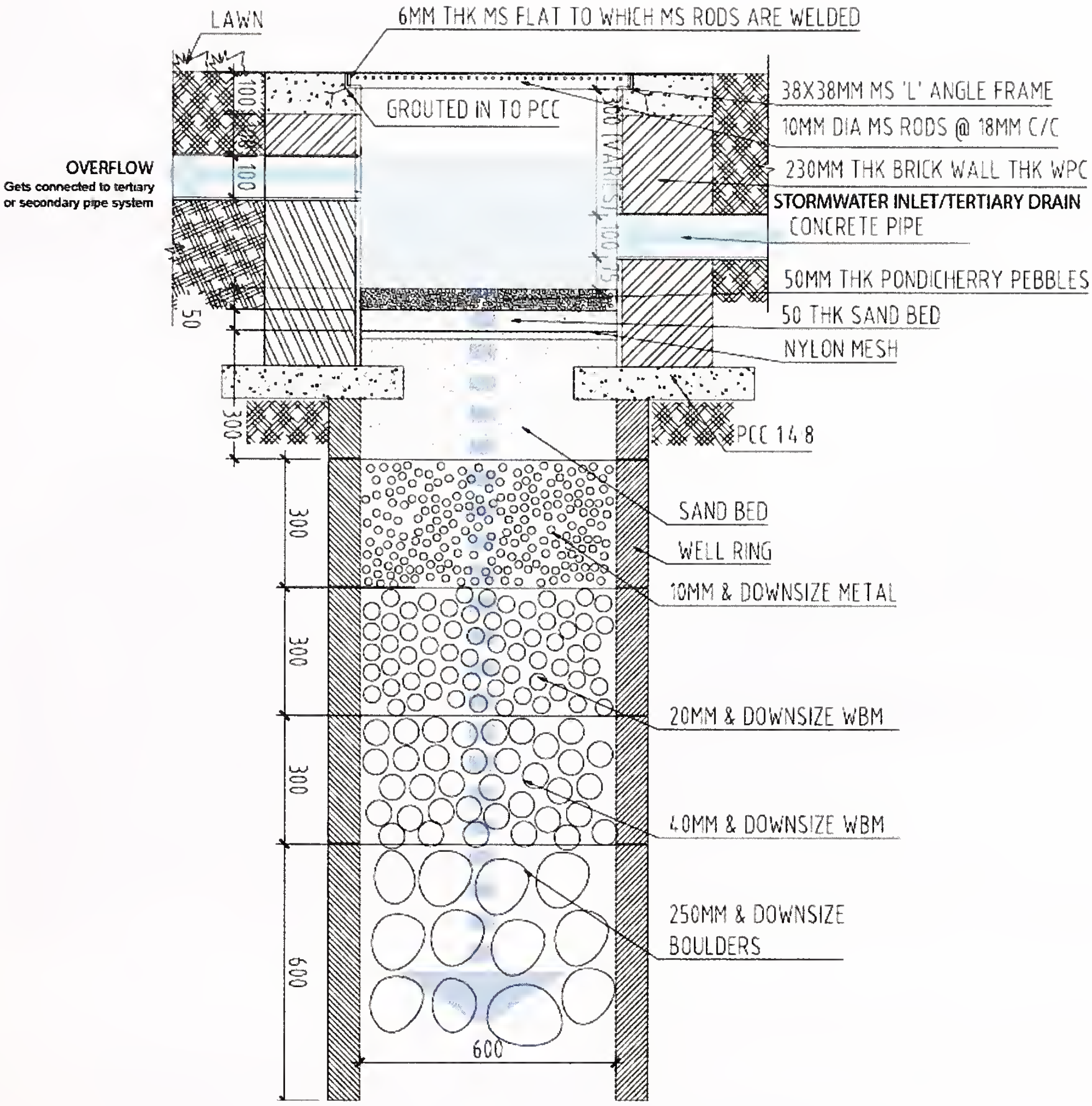
In the present scenario of depleted ground water in urban conglomerates all storm water drains shall be efficiently utilized for the benefit of raising the existing ground water table. This can be achieved by redesigning the existing drainage cross sections in such a way that storm water starts infiltration into ground at street level drain itself and continued through tertiary drains, secondary drains and primary drains. (Refer chapter 6 for classification of drains).

Before the ultimate disposal of rain water all possible methods shall be adopted for ground water recharging as ground water has depleted beyond 250 m in certain urban cities. It shall be commendable if ground water recharging starts at initial point of side drain of road itself. By the time storm water moves through tertiary, secondary and primary drains which shall have ground water recharging facilities, major quantity of storm water will get into the ground facilitating effective disposal system.

(a) Catch Basin with Infiltration Pit:



Typical Catch Basin Plan



Typical Selection Catch Basin with Infiltration Pit

4.1.2 *Types of filtration techniques*

a) Gravel Filters: See **Fig. 4.1 and 4.2**.

- Gravel filter can be designed with an impervious bottom or is placed on an impervious surface.
- Pollutant reduction is achieved as the water filters through the gravel & sand.
- Filters may be constructed in-ground or above grade, as they can include a waterproof lining.
- Gravel filters can be used next to road kerb or foundation walls, adjacent to property lines (if less than 750 mm in height), or on slopes.
- An overflow to an approved conveyance and disposal method will be required.
- Irrigation facilities to be given for non-monsoon season.

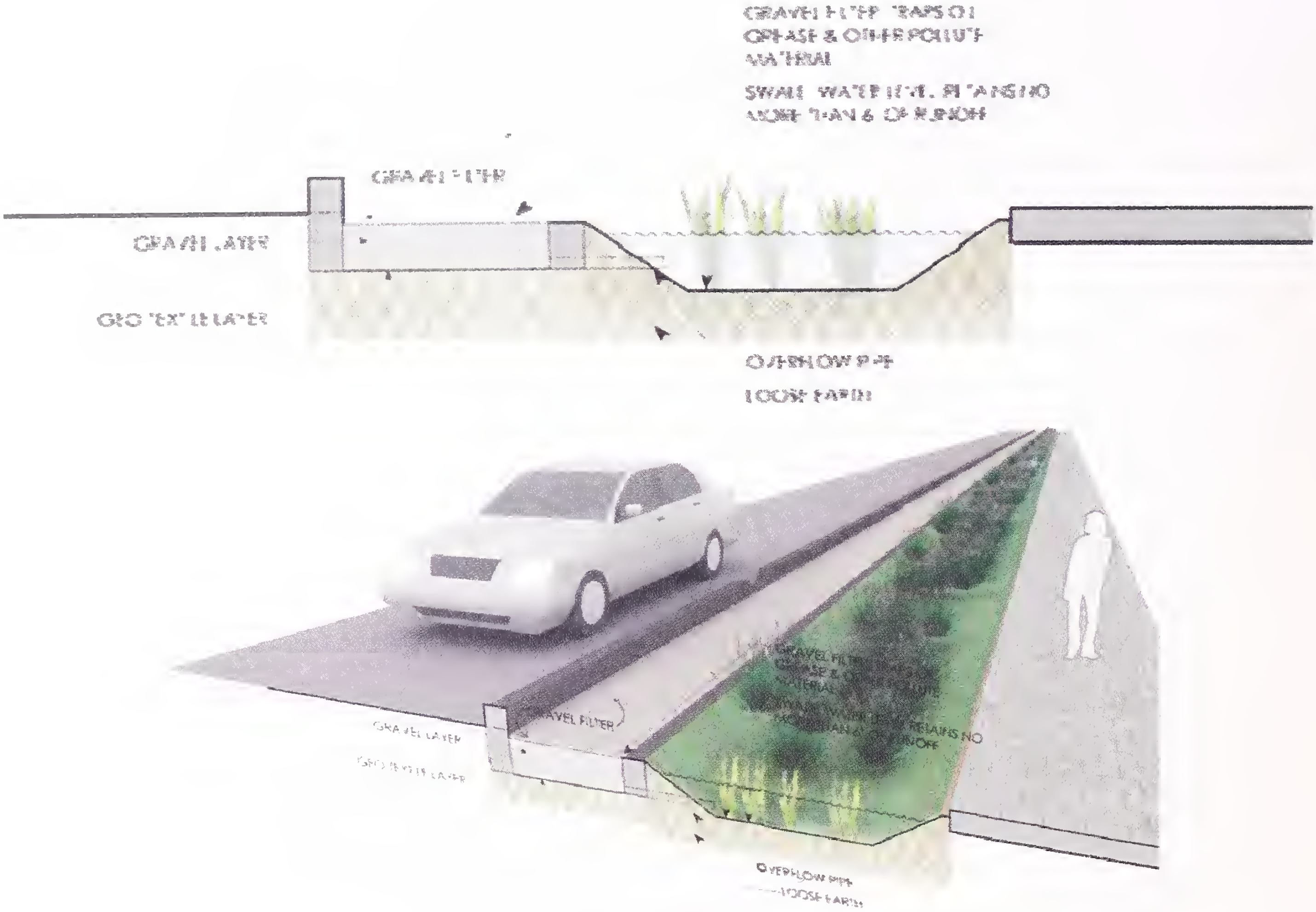
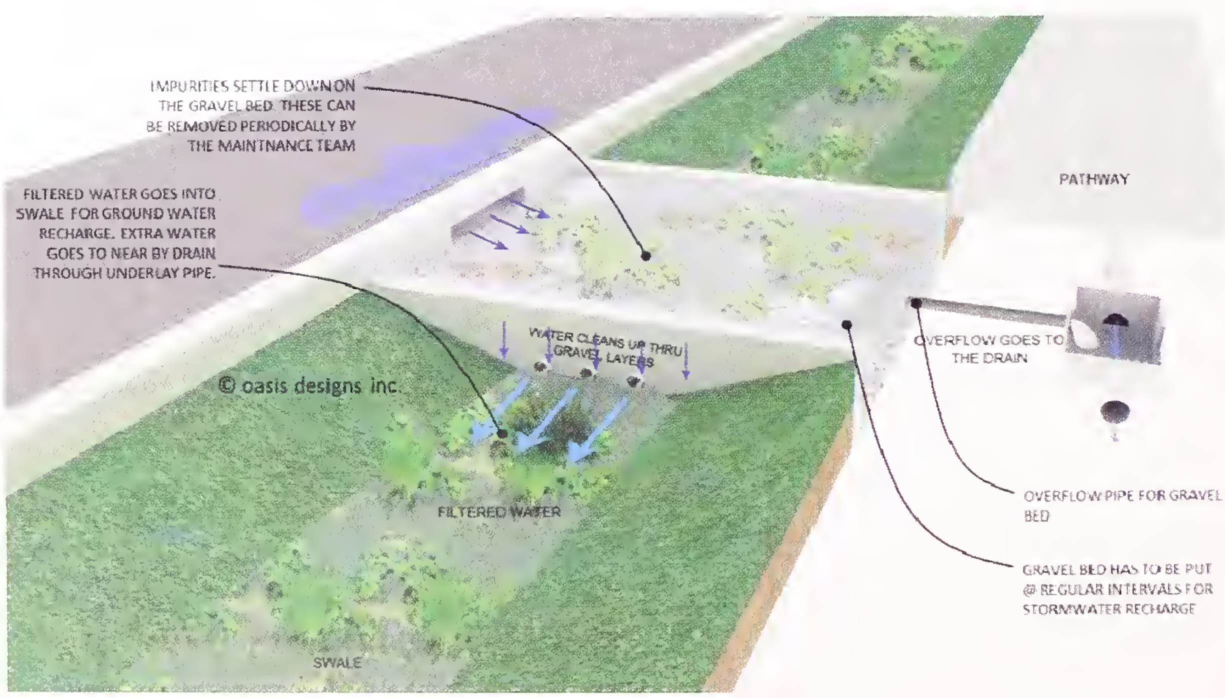


Fig. 4.1 Continuous Gravel Filter along Road



Gravel Filter Chamber at repetitive intervals

Fig. 4. 2

4.1.3 *Vegetated filters see **Fig. 4.3***

- Vegetated filter strips, or vegetated filters, are gently sloping areas used to filter, slow, and infiltrate stormwater flows.
- Stormwater enters the filter as sheet flow from an impervious surface. Flow control is achieved using the relatively large surface area, for slopes greater than 5 percent check dams or berms shall be provided.
- Pollutants are removed through filtration and sedimentation.

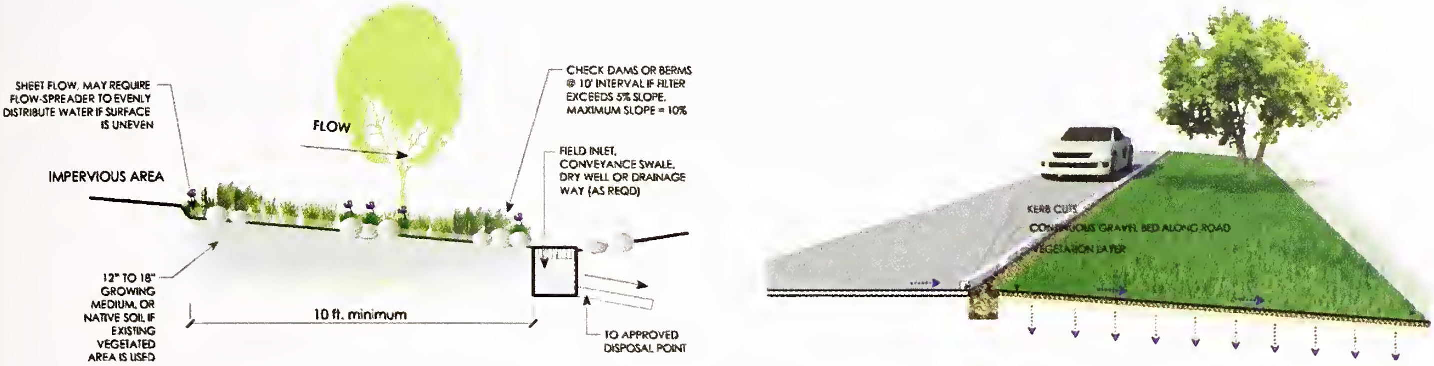


Fig. 4.3

4.1.4 *Riparian buffer see **Fig. 4.4***

- A riparian buffer is a vegetated strip along the banks of flowing water body.
- Riparian buffers are a simple, inexpensive way to protect and improve water quality through local plant materials.
- Buffer strips structurally stabilize banks and shorelines to prevent erosion. Trees and shrubs provide shade to maintain consistent water temperature necessary for the survival of some aquatic life.
- Width of the buffer is based on surrounding context, soil type, size and slope of catchment area, and vegetative cover.

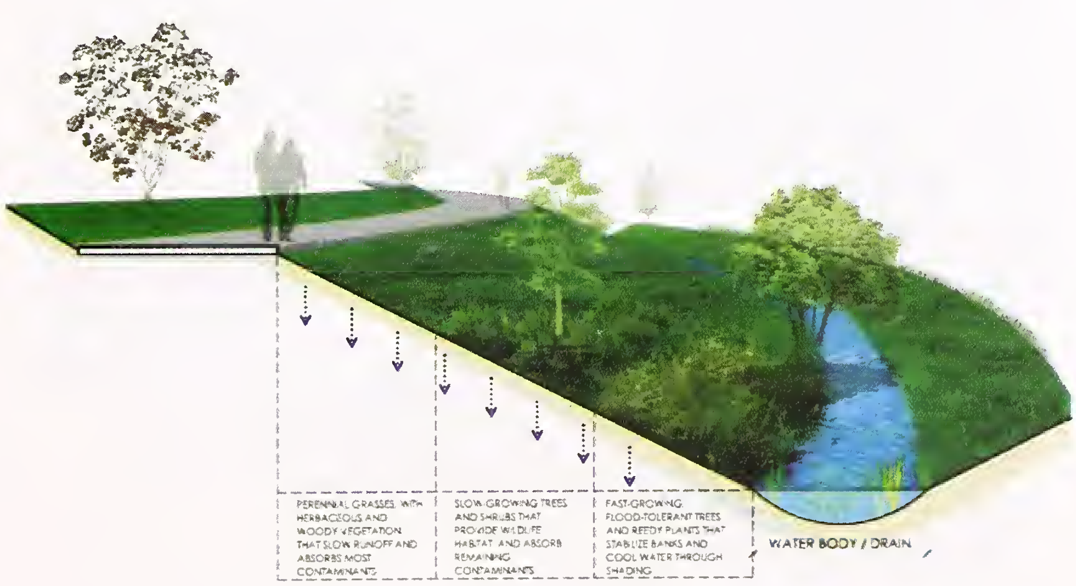


Fig. 4.4

4.1.5 *Conveyance*

Conveyance systems help storm water runoff to capture, convey, and potentially infiltrate before it moves downstream.

Types of Conveyance systems are:

a) **Bioswale : See Fig. 4.5 (a) (1) and 4.5 (a) (2)**

- A bioswale is a modified swale that uses bio retention media to improve water quality, reduce the runoff volume, and modulate the peak runoff rate while also providing conveyance of excess runoff.
- The bio swale typically has water tolerant vegetation permanently growing in the retained body of water.
- Uses biological process to remove a variety of pollutants
- Provides storm water treatment and conveyance
- Can be part of infrastructure within transportation Right of Way
- Can be a landscape feature
- Check dams, weirs, or stepped cells need to be used in areas with steep slopes

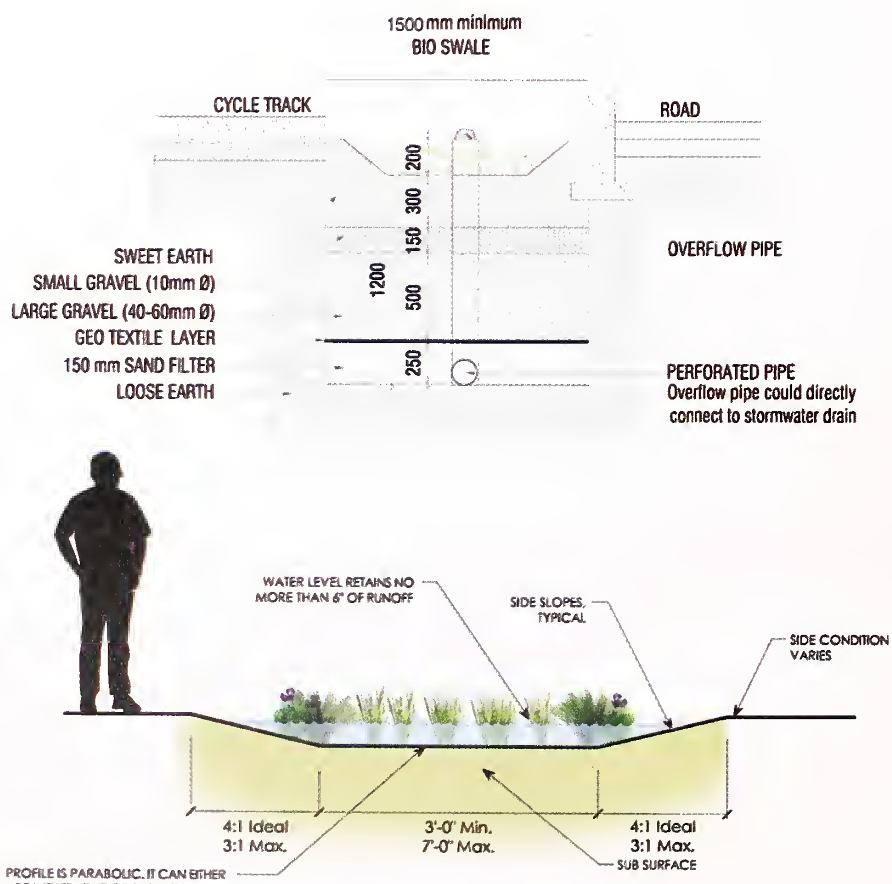


Fig. 4.5 (a) (1)

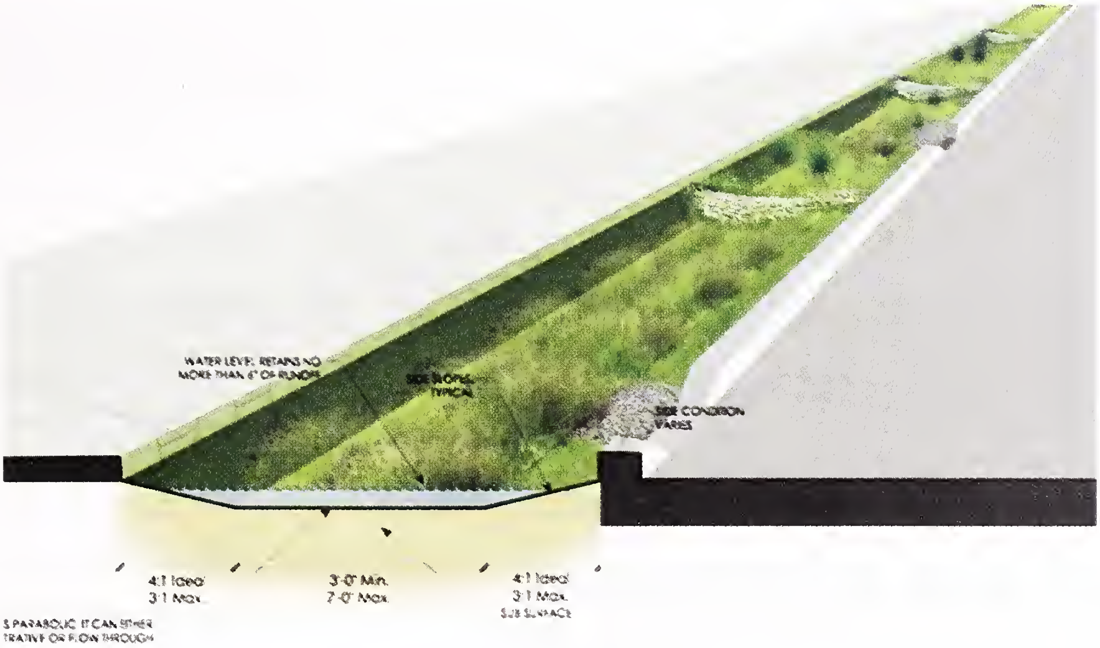
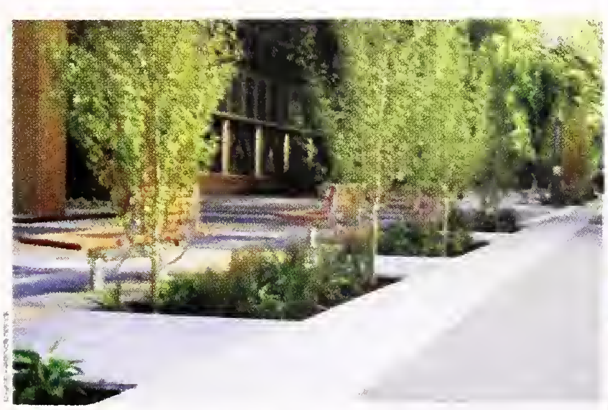


Fig. 4.5 (a) (2)

b) **Planters - See Photo 4.5 (b) (1) & (2)**

- Planters are contained landscape areas designed to capture and retain storm water runoff.
- Infiltration & Flow-through planters are structural landscaped reservoirs used to collect, filter, and infiltrate stormwater runoff.
- They allow pollutants to settle and filter out as the water percolates through the planter soil and infiltrates into the ground.
- Flow rates and volumes can also be managed with infiltration planters.

Planters



Green Street Featuring Continious Flow of Water

Retro Fitted Infiltration Planters

Planter Within Separator of Parking Lot

Photo 4.5 (b) (1)

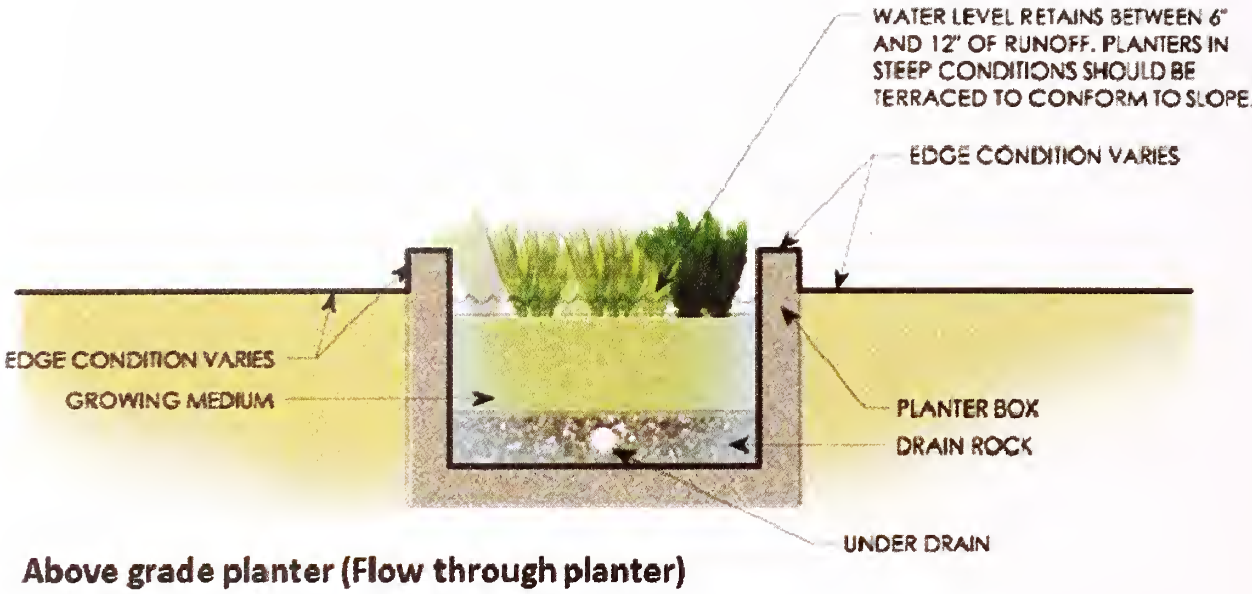


Photo 4.5 (b) (2)

c) **Green gutter: See Fig. 4.5 (c)**

- Green gutters are similar to Flow through planter with narrower width of the green area. Here the pollutant removal rate is less.
- They can often significantly "green" a street with minimal investment.
- Create a more walkable street environment by providing a green buffer between road traffic and the sidewalk.
- Require a long, continuous space to effectively slow and filter pollutants.
- These are very shallow and do not retain large amounts of runoff.

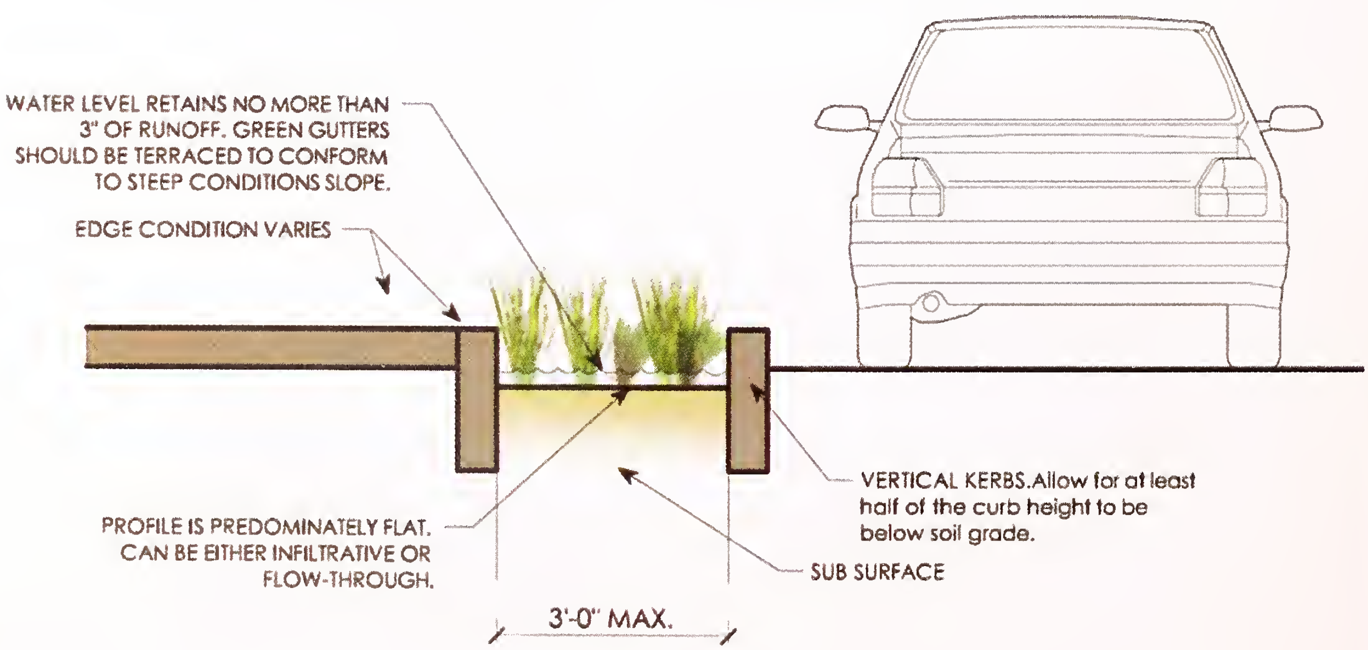


Fig. 4.5 (c)

The storm water released has to be controlled quantitatively and qualitatively by a temporary storage which is also called as detention/retention facility. Previous concepts which called for the rapid removal of storm water runoff from developed areas, usually by downstream channelization, are now being combined with methods for storing storm water runoff to prevent over loading of existing downstream drainage systems. The storage of storm water can reduce the frequency and extent of downstream flooding, soil erosion, sedimentation and water pollution. Worldwide, detention and retention facilities have been used to reduce the cost of large storm water drainage systems by reducing the required size for downstream storm water drain conveyance systems. The use of detention or retention facilities can reduce peak discharge from any watershed. The main objective of storm water management is to maintain the peak runoff rate from flooding, soil erosion, sedimentation and importantly prevention of pollution of ground water.

A detention facility is a storm water storage which can gradually release or weaken the force of runoff by way of a control structure or any similar mechanism. The retention facility is storage of storm water runoff and release via evaporation and infiltration only.

In the Indian scenario all the open tanks in urban limits and extended urban limits where storm water is being released can be effectively used as detention or retention facilities with necessary modifications. Important thing to bear in mind here is sewerage drains shall not be mixed up with storm water drains.

5 STORM WATER DRAINAGE SYSTEM AND APPURTENANCE

5.1 Classification of Urban Storm Water Drains

Drainage in the urban context is classified briefly as:

a) Primary Drains

b) Secondary Drains

c) Tertiary Drains

Primary Drains: These are natural drainage systems connecting series of major water bodies' upto disposal location in a particular catchment area. This originates as a tributary of a river basin and receives water from one or more watershed regions through secondary drainage network, tertiary drainage network or directly from road side drains during its course of flow.

Secondary Drains: These are natural or manmade network of drains connecting to primary drain or a water body. It originates from a particular water shed region and receives water from one or more micro watershed regions through tertiary drainage network or from road side drains during its course of flow.

Tertiary Drains: These are natural or manmade network of drains connecting to secondary drains or a water body. It originates from network of road side drains and receives water from micro watershed regions directly or through road side drains or in combination of both. Any

higher capacity road side drain when compared to normal road side drain is also a tertiary drain.

A master plan of existing network of primary and secondary drains shall be prepared for every city or town for future guidance and to check any encroachment or diversion of drains by individuals, particularly in new layouts.

5.2 The functional requirements of any drainage system will be its efficient disposal mechanism. Drainage water can be disposed off by:

a) Over the surface

b) In open channels

c) In covered drains

d) In flat terrain

Keeping in view the alarming decrease of ground water, and drawing water from deep underground which are leading to serious health hazards, the drainage system shall be effectively utilized for recharging in urban area's which will be boon, when implemented efficiently.

a) Drainage over the surface

The run-off of surface water will be at kerb side initially and later let off into drains through inlet structures, access holes and junction chambers.

As and when certain semi-urban areas and revenue pockets are merged into urban conglomerates, the areas would, have been under developed and the roads will normally be narrow resulting in non provision of drains. In such situations water shall be drained through gutter into main street drainage system where the minor street meets main road.

b) Drainage through open channel

The open drain along road side shall preferably be at the edge of right-of-way of road, as it has dual advantage of transportation of water as well as demarcation of road property. These drains are more efficient as they carry larger discharge particularly in flood conditions when drainage is surcharged. These drains are easier to maintain and allow for removal and disposal of silt and other solids.

c) Covered drains

Covered drains can be located at edge of right-of-way, below footpath or even below the carriageway, where the road is narrow, as in newly added areas/ revenue packets and road land is encroached, RCC box drains designed to take vehicular load may be provided. The location and size required can be accommodated at a suitable position in the right-of-way so that inspection,

silt removal and its disposal can be carried out without any hindrance. See **Photo 5.2**.

Photo 5.2 Box Drain in the Carriageway Portion of Road

Pipe drains also have the advantages but they shall be used for short lengths with required manholes at appropriate locations for maintenance and disposal of silt. Concrete pipe drains of appropriate shapes as circular, elliptical, pipe arch, horse shoe can be used with closely spaced manholes, as good mechanical equipment are available for cleaning and desilting. The disposal of storm water in such situations and in underpasses shall be carried out by gravity using 1200 mm size NP-3 pipes with necessary manhole at appropriate locations. However, whenever flow cannot be gravitational, same shall be converted to pumping.

Cost shall not be the governing factor in selecting a drainage system. For the purpose of long term maintenance, willingness of people to adopt to system and initial setting up cost shall be considered. It is preferable to have open drains for the ease of operation and maintenance. A drain along the boundary of main road with suitable inlets shall be considered. Drainage access to all properties shall be provided by means of properly designed outlets.

d) Flat Terrain

Disposal of storm water in flat terrain is a tricky affair, as conveyance will be very slow or nil due to zero or near zero gradient. The ideal mechanism in such situations is to increase the sectional dimensions of drains and introduce filter mediums in the external surface of drain, with necessary outlets, so that storm water can effectively be disposed off. Retention ponds at frequent intervals in available Government lands, parks, large private properties etc., shall be provided with necessary gradient for conveying system for disposal of water.

5.3 Disposal of Storm Water

It is essential to dispose off the rain water into one of the following natural bodies:

5.3.1 *River system*

5.3.2 *Coastal waters*

5.3.3 *Flood plains*

5.3.4 *Water bodies and natural reservoirs*

5.3.5 *Underground strata*

5.3.1 *River system:* Disposal of storm water into river system can be considered at locations if water is not being taken for water supply from its downstream side. Discharge of rain water into river needs to be allowed depending on the environmental conditions which shall be foreseen.

5.3.2 *Coastal areas:* Problems arising due to high tide shall be clearly understood. Similar would be the case when the ultimate disposal is into the river system. In most of such systems, during high floods sluice gates, which are controlled by flood department, are closed resulting in back flow. In such cases, where such a situation is likely to create critical conditions during heavy downpour, pumping may have to be resorted for discharging water above HFL. Self-regulatory holding ponds having sluice gates with one way water movement are a solution in tidal situations.

5.3.3 *Flood plains:* Possibility of demarcating some low laying areas where surplus water from the drains can be temporarily allowed to impound for some time may exist. Such systems shall be well designed not only for the entry of the storm water but for exit of the storm water. Also after retreat of storm, the drains do not no longer discharge their peak flows. Desilting of such ponds and maintaining of environment shall be well designed.

5.3.4 *Water bodies:* These had a historical and ecological significance but down the line due to urbanization, their size is reducing, encroached upon and many sewers open into them making it toxic tanks almost devoid of any life. Rapid urban growth and insensitive planning of road network is destroying natural heritage value which otherwise were directly used as natural catchment area. As on alternative, retention ponds at frequent intervals in available government lands, parks, large private properties etc., shall be provided with necessary gradient for conveying system for disposal of water.

5.3.5 *Underground strata:* There are many instances where storm water drainage leads to dead end, especially in large built-up areas. This happens due to poor topography to lead off storm water in thickly built-up areas. In such circumstances, only viable option is to dispose off the rain water into underground strata and further stagnated water needs to be pumped out.

Subsurface water is likely to get contaminated due to this system, where it needs careful examination. However as stated earlier due to depletion of ground water table, this method

of disposal in to sub surface will be of added advantage rather than considering its negative impact.

A vertical drainage disposal system into underground strata in built-up.

Area's is described briefly below:

The method is designed to dispose the storm water into the permeable strata below the ground level in built-up area, where there is no side drain functioning.

A vertical bore-hole of adequate diameter is made, the bottom of which is taken to at least 50 cm into the permeable layer. The bore-hole is then filled with brick bats or stone aggregates. To prevent clogging of the vertical drains, it is wrapped with non-woven geofabric or HDPE woven geofabric without lamination. The top portion of the vertical drain is covered with filter material for a depth of 15 cm.

The number and spacing and diameter of the drains depend upon:

i) The permeability of the strata at which the water is finally to be disposed.
ii) The rainfall of the area
iii) Extent of area to be covered

The vertical drain proposed may be constructed in conjunction with the horizontal drain to increase the rate of disposal. The vertical drain portion may also be modified by introducing a perforated PVC pipe wrapped with geotextile inside the bore-hole instead of filling it with brick bats. The method has been tried and found to be successful. The schematic arrangement for the system is shown in **Fig. 5.3** Any alternate method suiting to local soil condition shall be adopted for satisfactory disposal of rain water.

5.4 Design Objectives

The primary objective of road drainage design is to provide for safe passage of vehicles during the design storm event. The drainage system is designed to collect storm water run-off from the road way surface and right-of-way, convey it along and through the right-of-way, and discharge it to an infiltration system for ground water recharging and balance into a receiving body without causing adverse site impacts.

The conveying system of storm water which includes drainages, ditches, channels, pumps etc, to provide an efficient mechanism of conveying design flows from inlet locations to the discharge point without surcharging inlets and also without causing surface flooding. Erosion potential of flow shall also be considered in design of open channels and other flow systems used for storm water conveyance.

The ground water disposal and storm water collection systems shall be designed to provide adequate surface drainage. Traffic safety is intimately related to the surface drainage. Rapid removal of storm water from the pavement minimizes the unsafe conditions which can result in hazards of hydroplaning. Surface drainage is a function of transverse and longitudinal pavement roughness, inlet spacing and inlet capacity.

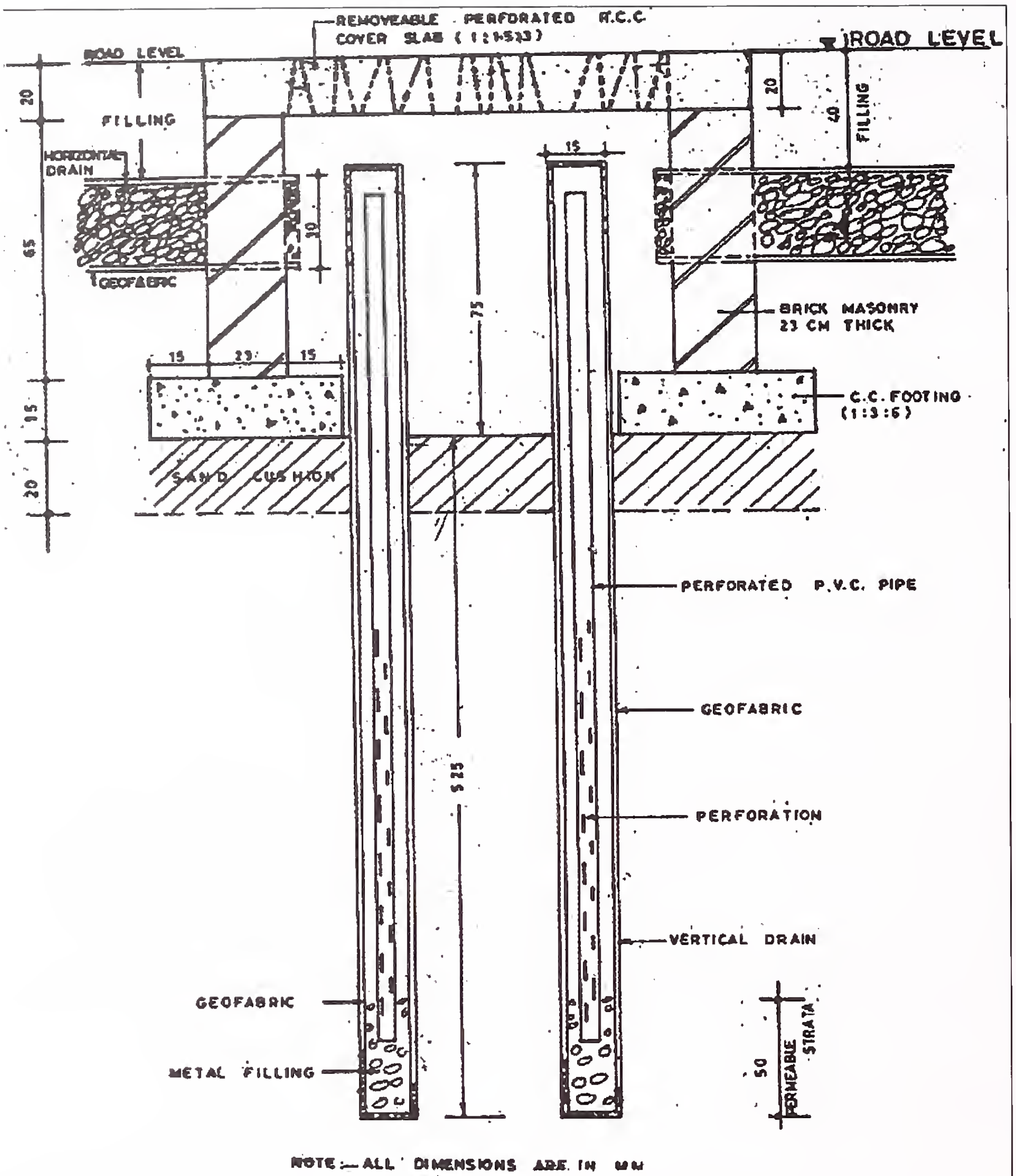


Fig. 5.3 Cross-Section of Vertical Drain

The discharge design facilities for storm water collection and conveyance systems include consideration of storm water quantity and quality. Urban, State or Union government regulations often control the allowable quantity and quality of storm water discharges. To meet these regulatory requirements, storm water drainage systems will usually require detention or retention basins and/or other best management practices for the control of discharge.

General considerations in design of storm water drain:

a) Drains should be planned taking into consideration the ground levels, slope of the ground, valley and ridges and also the land uses planned for urban development.

b) Drains should be planned to get good longitudinal slope, considering the nature of soil and subsoil water level. Drainage of large area can be better

achieved by subdividing it into small grids to avoid a long main drain. Aim should be to get a high velocity for the dominant flow.

c) Efficiency in maintenance of drainage system should be an important consideration in selecting the size, (covered or open) shape and the location. The specification of the drain should also aim at preventing the possibility of ingress of other extraneous materials, debris, rubbish, vegetation etc. where gratings are provided on drains, they should be so located as to attract attention of maintenance staff, easy to approach, inspect and clean it.

d) An attempt shall be made in the design to provide higher starting and higher outfall bed levels in drains. A free outfall shall be attempted as far as possible.

e) Design of the main drain shall be so made as to allow use of the all methods including mechanical type for desilting operation. This shall include vehicles to get in drain for desilting.

5.5 Appurtenances

For efficient functioning of storm water drainage system, certain appurtenant structures are essential. Storm water drain inlets are used to collect run-off and discharge it to drainage system. These are the devices meant to admit the surface runoff to the drain and form a very important part of the system. Their locations and design shall, therefore, be given careful consideration. Inlets are typically located in gutter sections, paved medians, road side and median ditches. Storm water inlets can be categorized in to following five groups:

1) Grate inlets
2) Kerb-opening inlets
3) Slotted inlets
4) Combination inlets
5) Manholes
6) Bell Mouth Inlet

Grate inlets are opening in the gutter covered by a grating. Kerb opening inlets are vertical openings in the road kerb covered by a top slab through which storm water flows. Slotted inlets consist of a pipe cut along the longitudinal axis with bars perpendicular to the opening to maintain the slotted opening. Combination inlets consist of both a kerb opening inlet and a grate inlet placed in a side-by-side configuration. **Fig. 5.5 (a)** illustrates each class of inlets.

Grate inlets perform satisfactory over a wide range of gutter grades. Grate inlet is generally loose capacity with increase in grade, but to a lesser degree than kerb inlets. **Fig. 5.5 (a) Photo.5.5 (a)** shows varieties of grate inlets. The basic advantages of grate inlets are that they are installed along the roadway where the water is flowing. Their disadvantage is that they may be clogged by floating trash or debris. For safety reasons, preference shall be given

to grate inlets. Also missing gratings may cause accidents particularly for light motor vehicles and two wheelers.

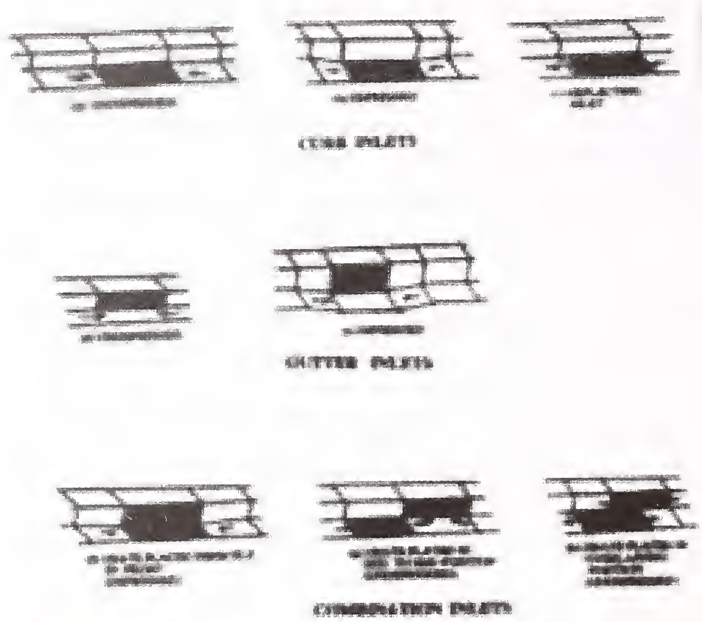


Fig. 5.5 (a) Various Types of Kerb Inlets

Photo 5.5 (a) Varieties of Grate Inlets

Various types of - inlets are vertical openings in the road kerbs through which the storm water flows and is preferred where heavy traffic is anticipated. They are termed as deflector inlets. This type of drain inlets does not interfere with the flow of traffic as the top level of these deflectors lie in the plane of the pavement. See **Photo's 5.5 (b).**

Photo 5.5 (b) Different-types of Kerb Openings

Combination inlets provide the advantages of both kerb opening and grate inlets. This combination results in a high capacity inlet which offers the advantage of both grate and kerb opening inlets. When the kerb opening precedes the grate in a sweeper configuration, the kerb opening inlet acts as a trash interceptor during the initial phases of storm. When used in a sag configuration, the sweeper inlet can have a kerb opening on both sides of the grate.

Slotted drain inlets can be used in areas where it is desirable to intercept sheet flow before it crosses into section of roadway. Primary advantage is their ability to intercept flow over a wide section. However slotted inlets are very susceptible to clogging from sediments and debris and are not recommended for use in environments where significant sediment or debris loads may be present. Slotted inlets on a longitudinal grade do have same hydraulic capacity as kerb openings when debris is not a factor. **Fig. 5.5 (b) & (c)** indicate different types of openings.

Bell Mouth Inlet

In Urban areas, where a footpath is made and the location of the drain is adjacent to it, water inlet in many cases, is through a RCC pipe. This is 250 mm dia NP class pipe. The spacing is depending upon the area to the drained and the longitudinal slope of the road. Schamatic arrangement is shown in **Fig. 5.5 (a)**.

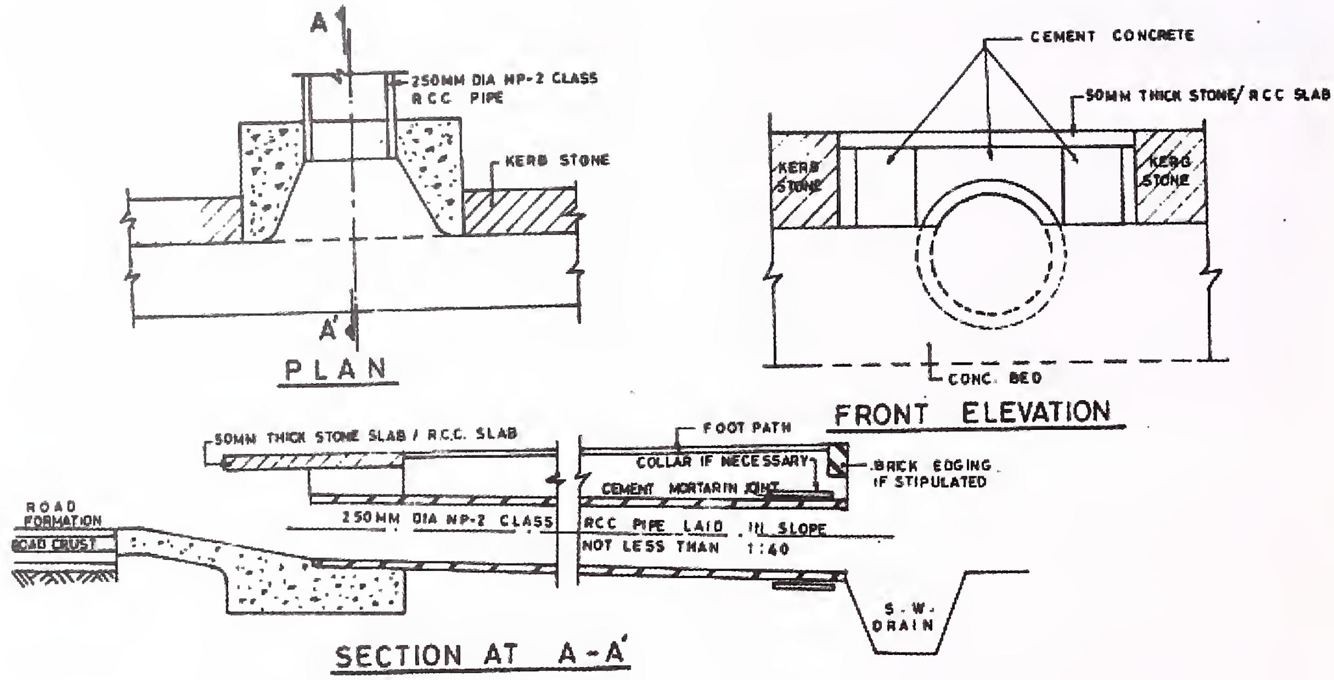


Fig. 5.5 (a) Schematic Arrangement Showing Bell Mouth Drain

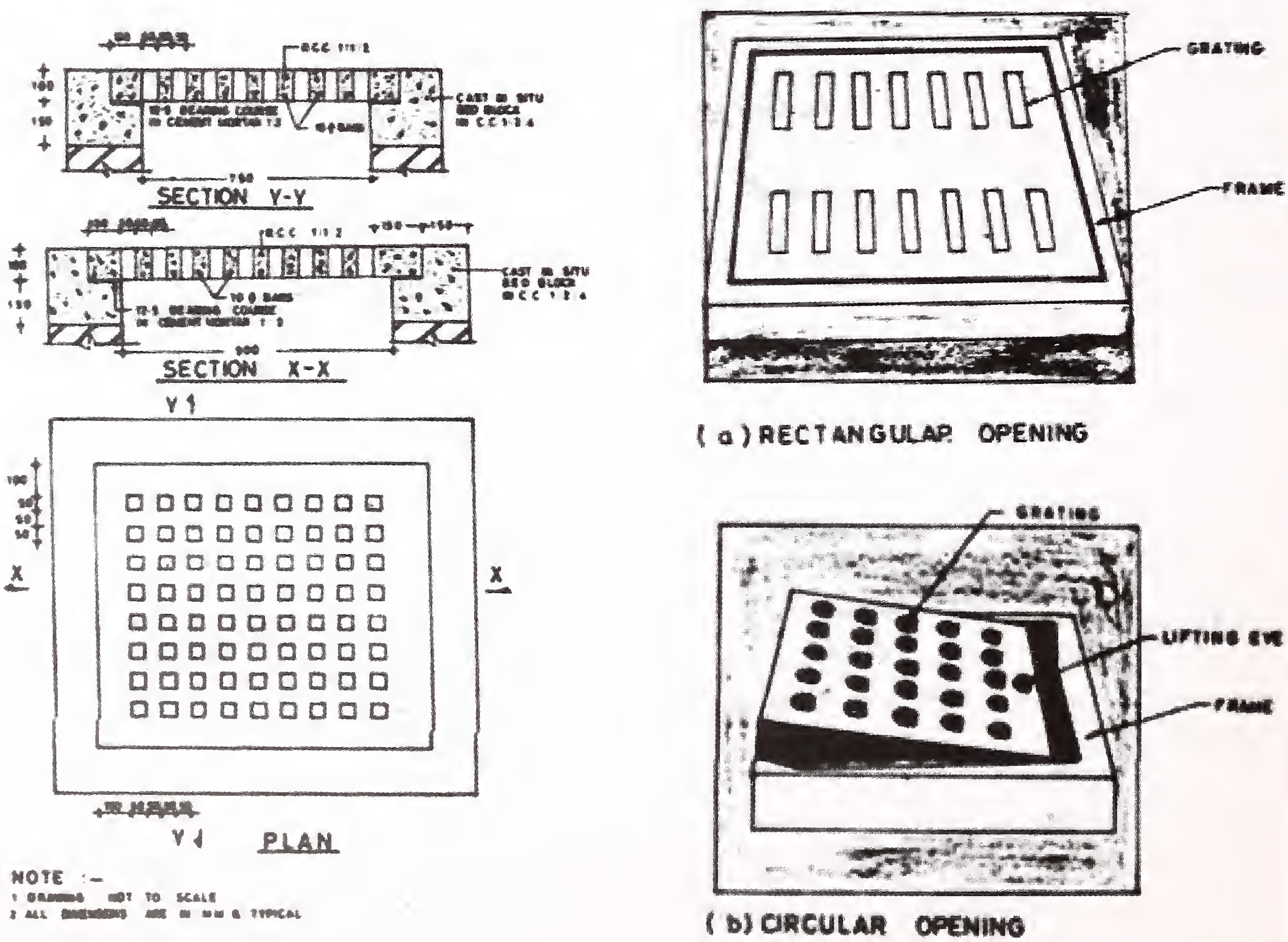


Fig. 5.5 (b) Grating and Frame made of Fiber Reinforced Concrete

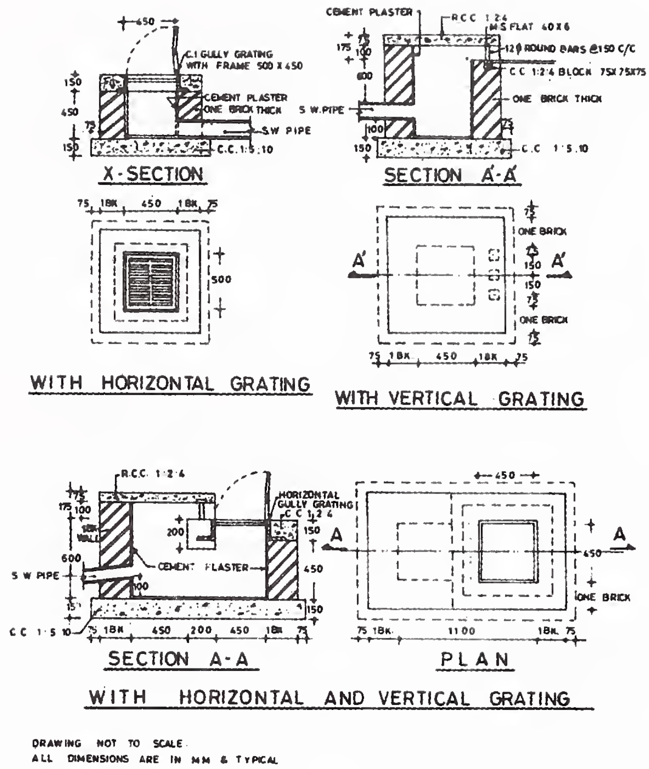


Fig. 5.5 (c) Road Gully Chamber

MANHOLES are the openings constructed on the alignment of a covered or pipe drain and its primary function is to provide convenient access to the storm water drainage system for inspection and maintenance. The secondary functions of manholes are they serve as, flow junctions, can provide ventilation and pressure relief for storm water drainage system. The spacing of manholes depends on local agencies, past experience and maintenance equipment limitations. Manholes shall be located taking into account of the following conditions:

i) When two or more storm water drains converge,

ii) When pipe sizes change,

iii) When change in alignments occurs and

iv) When change in grade occurs

Generally manholes in straight reaches are at a spacing of 10 m to 20 m. A typical schematic arrangement of manhole is shown in **Fig. 5.5 (d)**.

Manholes can be of circular, square, rectangular or any suitable shape but opening for entry into the manhole shall not be less than 500 mm clear. A circular opening is generally preferred. Inside dimensions of manhole shall be adequate to permit inspection and maintenance without difficulty. Minimum inside dimension of manhole shall be of 1200 mm x 900 mm. In case of shallow manholes upto depth of 1.40 m, minimum allowable width could be reduced to 750 mm. Manhole covers and frames shall be factory made with fiber reinforced or reinforced, so that higher level of quality control exists. They are available in following grades:

a) L.D-2.5 - suitable for use with pedestrian load and occasionally LMV traffic. Can be used where no vehicular traffic is involved.

b) MD-10 – These are suitable for use in service lanes/roads, car parking area's etc.

c) MD-20 – These are suitable for use in carriage way with heavy duty vehicular traffic.

d) EAD-35 – These are suitable for use on carriage way in Commercial/industrial/ post areas

The suffix on above type indicates the ultimate breaking load in MT using 300 mm dia block, as per methods described in IS:12592 (Part-1). The precast manhole covers are suitably marked on the operative surface with details like name of the department, grade, and date of manufacture, trade name, sewer or SWD. They should have edge protection of covers and lifting facility for proper serviceability

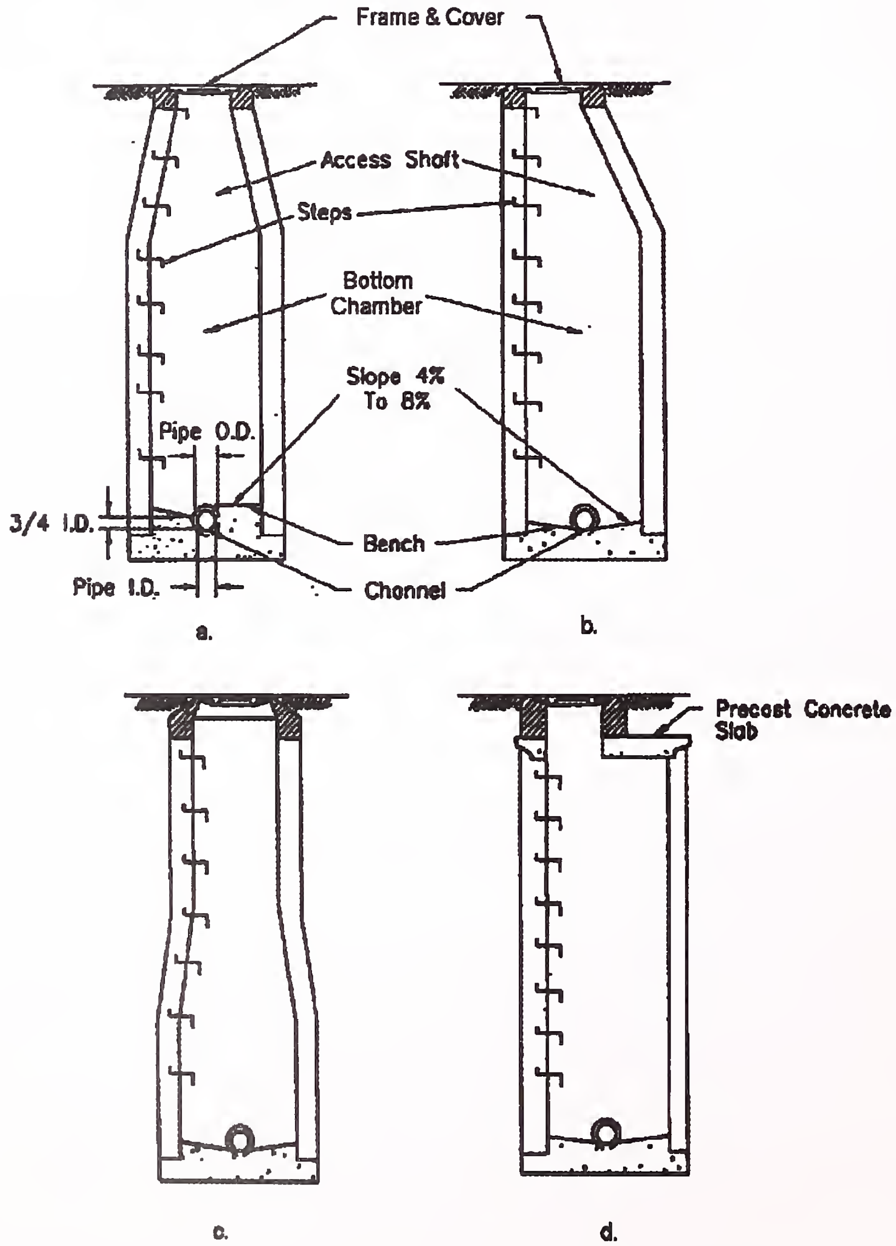


Fig. 5.5 (d) Schematic Arrangement of Manhole

6 STORM WATER DRAINAGE DESIGN

6.1 Prior to commencement of design, system planning is essential to the successful development of storm water drainage design. Urban drainage design shall be a component of overall urban planning. The design of drainage system shall mainly comprise of (i) collection of storm water (ii) conveying (iii) and discharging to an adequate receiving body. The design approach shall be collection of data, coordination between various interested agencies, preliminary development of concept, refinement of concept and design.

6.2 **The design of drainage system involves:**

6.2.1 *Calculation of total discharge that the system is required to drain off.*

6.2.2 *Fixing the dimensions and slope of the drain to have adequate capacity to carry the discharge and also easy on its maintenance*

6.2.1 Calculation of total discharge that the system is required to drain off. The discharge is dependent upon intensity and duration of precipitation characteristics of the area and the time required for such flow to reach the drain. The storm water flow for this purpose may be determined by using the rational method, hydrograph method, rainfall runoff correlation studies, digital computer models and empirical formulae. The empirical formulae that are available for estimating the storm water runoff can be used only when comparable conditions to those for which the equations are derived initially can be assured. Of the different methods available, the rational methods is most commonly used and serves the purpose for design of road side drains satisfactorily.

6.2.2 There is a need to fixing the dimensions and slope of the drain to have adequate capacity to carry the discharge and also easy on its maintenance. Rainfall data of the concerned area shall be analyzed by any suitable method of forecasting. Road side drains are not designed for the peak flow of rare occurrences such as once in 50 to100 years – as is the case with design of important structures such as bridges or weirs. However, it is necessary to provide adequate capacity to prevent frequent flooding of the drainage area. There may be some water accumulation on the roads when the rain fall exceeds the design value which has to be permitted. The frequency of occurrence which can be permitted varies from place to place, depending upon the importance of the place. Flooding at any time, however, causes inconvenience to people but it shall be accepted once in a while considering the savings affected in drainage costs. The areas such as important junctions, areas having basement, substations etc. should be considered as important areas and higher frequency of flooding shall be adopted in the design. Based on the practice being followed in metropolitan cities in our country and considerations of cost in mind, it is recommended that a return period to 1 to 2 years be adopted in estimation of runoff.

6.3 Time of concentration: It is the time required for the maximum runoff rate to develop. It is equal to the time required for a drop of water to run from the most remote point

of the road surface to the point for which the runoff is being estimate. Empirical formula (IRC:SP:13) may be referred to determine the time of concentration:

$$L_c = (0.87) \quad \frac{(L^3)^{0.385}}{(H)}$$

Where

L_c	=	time of concentration in hours
L	=	Distance of critical point of the drain in km
H	=	Fall in level from the critical point to the drain level in meters.

For a critical area, the time of concentration is made up of two components. These components are inlet time i.e., the time required for the rain water to flow over the road surface and enter the drain at various inlets into the drain and the time of flow. The time of flow is the time required for water to flow through the drain from the starting point upto the critical section under examination. It is to be remembered that flow time would be different for different points in the drainage system. This is illustrated through an example. Referring to **Fig. 6.1**, water from area A enters the drainage system at 2, and water from area B enters at 3. The time of concentration in this case is made up of inlet time, which takes into concentration for area A in which the drain starts and the time of flow in the drain from 2 to 3. If the inlet time is 5 minutes and the flow time is 3 minutes, the time of concentration at 3 is 8 minutes. Time of concentration for water at 4 to reach inlet at 3 is 9 minutes. If the rainfall duration is less than 8 minutes, not all of the area A and B would be contributing because water from more remote points of A fail to arrive to point 3.

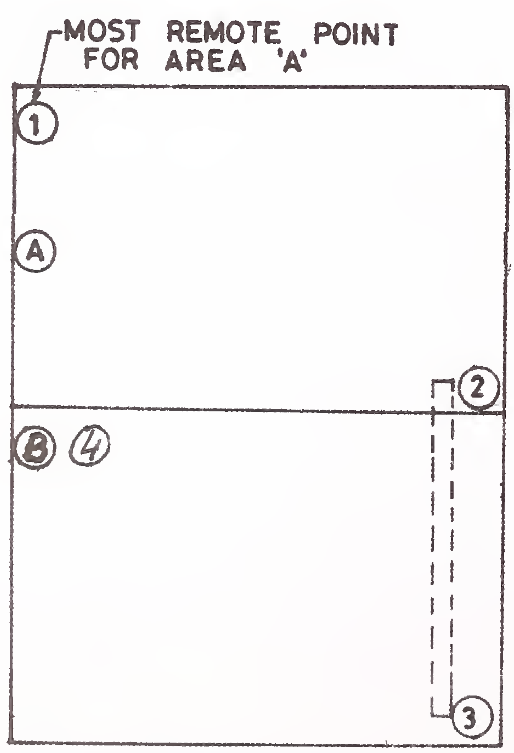


Fig. 6.1 Time of Concentration

6.3.1 The method described above can be used for each storm line to the outlet for arriving at the time of concentration. At every point under consideration, the inlet time at the most remote end of the drain is added to the total flow time in the drain. Inlet time used in actual practice may vary from 5 to 10 minutes. Experience or investigation will be needed in arriving at the proper value, though this factor decreases in importance as the area or the length of the drain increases, and inlet time becomes a small proportion of the time of concentration.

6.4 Rainfall intensity: It has been observed that shorter the duration of critical rainfall, the greater would be the expected average intensity during that period. For example, during a 30 minute rainfall, some 5 minute period, or any period less than 30 minutes in length, will have an average rainfall intensity greater than that of the whole storm. The critical duration of rainfall will be which produces maximum runoff. This duration is equal to the time of concentration, since shorter periods do not allow the whole area to contribute water, and longer duration will give a smaller average rainfall intensity. The problem, thus reduces to one of establishing a relationship between time of rainfall duration and probable or expected rainfall intensity. For the design purpose, high intensities are of importance.

6.4.1 Current practice being followed in some of the metropolitan cities is as follows:-

i) Mumbai

The runoff coefficient adopted in fully developed area is 1.0. In less developed areas the coefficient is worked out which may range between 0.58 to 1.0. The critical intensity of rainfall is considered 50 mm per hour and the frequency of the storm 2 times a year.

The criteria for design depth are not to allow flooding of 15 cm above G.L.

ii) Chennai

The intensity of rainfall adopted is 25 mm per hour. This roughly corresponds to rainfall intensity of 60 minutes duration with a frequency of 1 in 1.25 years.

iii) Delhi

The average value of runoff which is adopted for different category of drains is as follows:-

a)	Internal drains (0.177m^3/ha)	1 cft/acre
b)	Intercepting drains (0.132m^3/ha)	0.75 cusec/acre
c)	Main drain (0.088 m^3/ha)	0.5 cusec/acre

6.4.2 The above values have been worked out on following assumptions. Rainfall intensity of 30 minutes duration at the rate 2.5" (62.5 mm) per hour occurs once in two years. Time of concentration 30 minutes and the average runoff coefficient adopted is 0.60.

This gives average runoff for internal drains as 0.88 cum/ha. Considering that flooding at streets for an hour or so may be allowed and the drains are designed for a runoff of 1 cusec/ acre.

For intercepting drains, time of concentration considered in 30 minutes and runoff coefficient adopted is 0.4. The average runoff is taken as 0.13 cum/ha cusec/acre as against calculated value of 0.177 cum/ha. In case of main drains, time of concentration considered is one hour and the corresponding intensity of rainfall as 42 mm (1.65") per hour occurring once in 2 years. The average runoff coefficient adopted is 0.30 which gives runoff 0.5 cusec/acre.

6.4.3 Intensity is expected to vary in different parts of the country. Though the rainfall gauges installed by the Meteorological Department and other Government Organizations are not numerous enough to give entirely satisfactory data, but sufficient information is available to allow adoption of rainfall intensity and designer is not required to make guesses. Smaller cities that do not have a rainfall gauge station should install their own gauge and begin accumulating rainfall records for future use in design. While obtaining data from the India Meteorological Department (IMD) an important fact to be born in mind is that the processing of data by IMD is mainly for arriving at the design flood of a specific return period – usually 50 years, for fixing water ways, design HFL etc. for important streams and the data is not ready made for the specific purpose of design of road side drains.

6.5 For the estimation of flood discharge, Central Water Commission (CWC), jointly with India Meteorological Department (IMD), RDSO, Ministry of Railways and Ministry of Surface Transport has compiled very useful data. The entire country has been divided into 26 hydro meteorological homogeneous subzones as can be seen in **Fig. 6.2**. Twenty (20) flood estimation reports covering hydro meteorological studies for 23 subzones have already been published. The report includes the detailed rainfall studies of various stations having Ordinary Rain Gauge (ORG) and Self Recording Rain Gauge (SRRG) installed by the IMD and the state Governments. In case of ORG locations, the data available is in terms of daily rainfall i.e., highest one day station rainfall (24 hours rainfall ending 0830 hrs of date) along with date of occurrence. In case of SRRG stations, data available is the heaviest storm rainfall in durations of 24, 12, 6, 3 & 1 hour along with date and time of occurrence. For some selected locations data for half an hour rainfall is also available. In locations where only 24 hour rainfall data is available, the same can be converted into short duration rainfall (shortest duration 1 hour) by adopting conversion factor in the report. The conversion factor varies from zone to zone and the one applicable for the design zone should be adopted. As an example, the graph showing duration vs conversion ratio applicable for Western Himalayas (zone-7) is reproduced in **Fig. 6.3.** Due to their specific requirement, the data available with CWC, IMD etc. is limited to minimum period of one hour, whereas, for the design of storm water drains, depending upon the time of concentration, periods may be less than 1 hour.

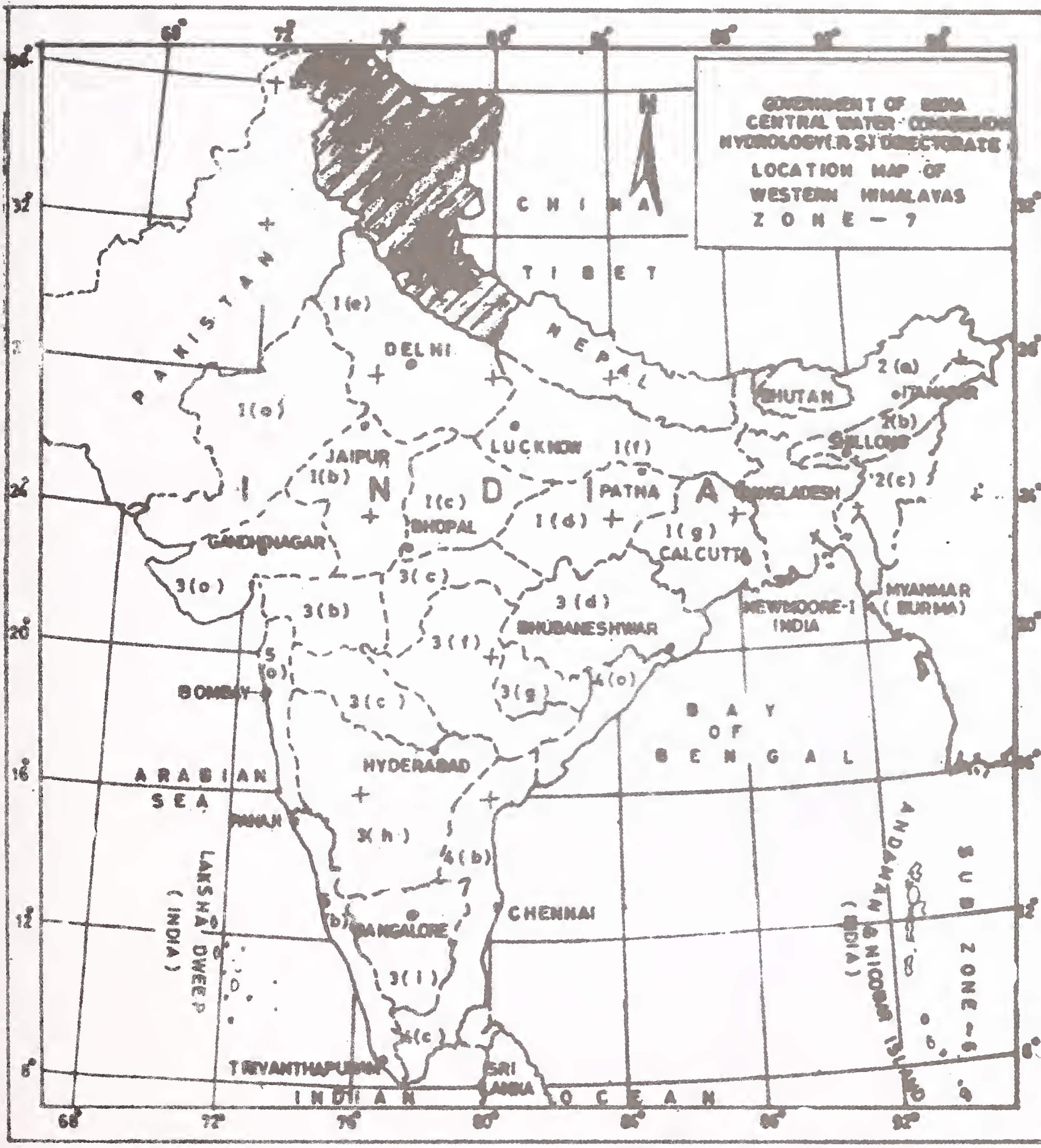

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (R.S.) DIRECTORATE
LOCATION MAP OF
WESTERN HIMALAYAS
ZONE – 7
CHINA
TIBET
NEPAL
PAKISTAN
INDIA
DELHI
JAIPUR
LUCKNOW
PATNA
BHOPAL
GANDHINAGAR
CALCUTTA
BHUTAN
SHILLONG
BANGLADESH
MYANMAR (BURMA)
BHUBANESHWAR
BOMBAY
HYDERABAD
BAY OF BENGAL
ARABIAN SEA
CHENNAI
BANGALORE
LAKSHADWEEP (INDIA)
ANDAMAN & NICOBAR ISLAND (INDIA)
SUB ZONE – 6
TRIVANTHAPURAM
SRI LANKA
INDIAN OCEAN
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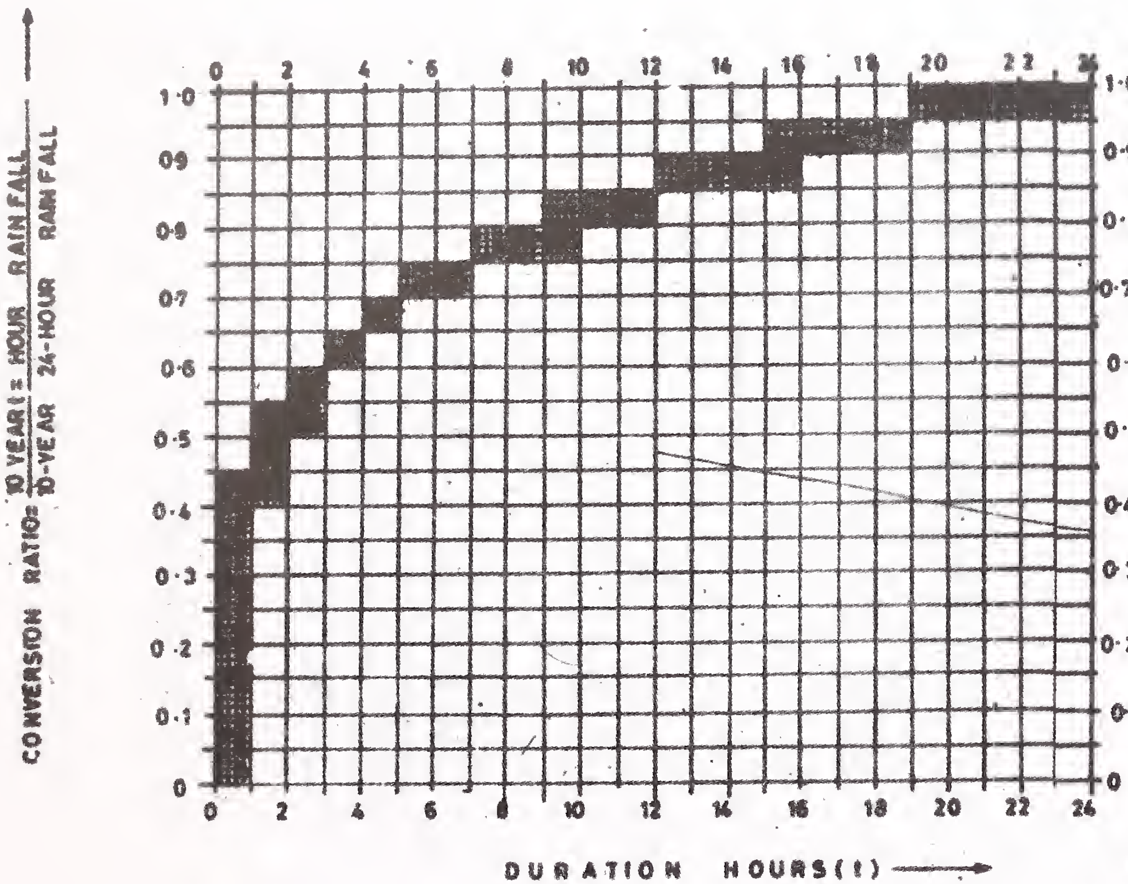
Fig. 6.2



RATIOS FOR 24-HOUR POINT RAIN FALL TO SHORT DURATION RAINFALL

DURATION (HOURS)	RATIOS
1	0·425
2	0·530
3	0·400
4	0·650
5	0·695
6	0·725
7	0·750
8	0·770
9	0·790
10	0·810
11	0·830
12	0·845
13	0·860
14	0·880
15	0·890
16	0·910
17	0·920
18	0·935
19	0·950
20	0·960
21	0·970
22	0·980
23	0·990
24	1·000

CURVE SUPPLIED BY INDIAN METEROROLOGY DEPARTMENT

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION
HYDROLOGY (REGIONAL STUDIES) DTE.

WESTERN HIMALAYAS
ZONE — 7
DURATION VS CONVERSION RATIO

Fig. 6.3 Conversion of Short Duration Rain Fall to 24 hour Rainfall

6.6 The best possible estimation is possible where the gauge records at the intervals of 5, 10, 15, 20, 30, 40, 50, 60 and 90 minutes are available. Method using such a data for obtaining intensity of rainfall for a particular duration of any duration is given in below.

COMPUTATION OF INTENSITY OF RAINFALL FOR A PARTICULAR STORM DURATION

a) Rainfall data for a particular city is available for 26 years. The analysis of data gives the frequency of storms of stated intensity and durations which is given in Table A.1.1..

Table A.1.1.

Duration in minutes	No. of storms of stated intensity or more for a period of 26 years (mm/hr)								
	30	35	40	45	50	60	75	100	125
5					100	40	18	10	2
10			90	72	41	25	10	5	1
15		82	75	45	20	12	5	1	
20	83	62	51	31	10	9	4	2	
30	73	40	22	10	8	4			
40	34	16	8	4	2	1			
50	18	8	4	3	1				
60	8	4	2	1					
90	4	2							

b) The stepped line indicates the location of the storm occurring once in two years i.e. 13 times in 26 years. The time intensity values for this frequency, i.e. once in two years are then obtianed by interpolation and is as given in Table A.1.2. :

Table A.1.2.

i (mm/hr)	30	35	40	45	50	60	75
t (min)	51.67		36.48		16.50		8.12
		43.75		26.57		14.62	

c) Any one of the following equations can be used :

$$i = \frac{a}{t^n} \qquad \text{..... (i)}$$

or

$$i = \frac{a}{t+b} \qquad \text{..... (ii)}$$

Where,

i = intensity of rainfall in mm/hr

t = duration of storm in minutes.

And a, b & n are constants which are dependent upon rainfall characteristics of a particular area and will not be same for all parts of country. It is more convenient to obtain the value of 'I' for any particular time't' using graphical form. The equation (i) gives a straight line when plotted on a double log paper and equation (ii) gives a straight line when reciprocal of i is plotted against t on a arithmetical graph paper.

In **Fig. A-1.1**, 1/i has been plotted against t for the particular station and best fitting straight line obtained. Now, the value of 1/i can be read against given value of t. For example, using the graph:

i for t = 20 minutes will be 59.7 mm/hr

i for t = 10 minutes will be 52.6 mm/hr

d) Method is also illustrated for storm frequency of one year using equation (i). Time intensity values for one year frequency as obtained from Table below may be suitably interpolated.

Table A.1.3

i (mm/hr)	30	35	40	45	50	60
t (min)	44	36	28.5	22.5	13.5	9.75

The best fit plot is given in Fig. below from which for any value of 'i', can be read for a given't' using this figure,

for t = 20 minutes, i = 44 mm/hr and,

for t = 10 minutes, i = 56 mm/hr

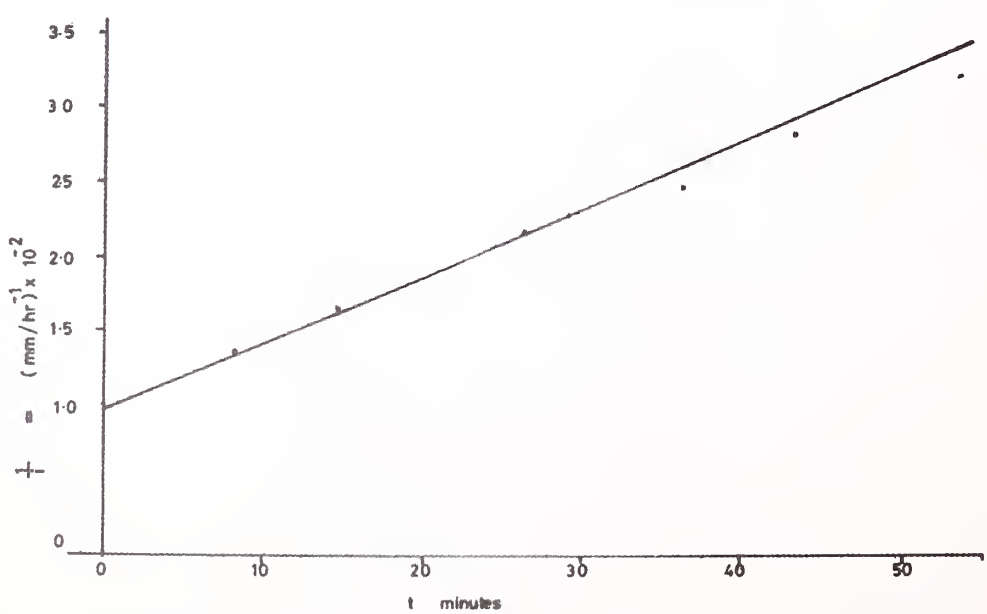


Fig. A-1.1 Graph between Reciprocal of Intensity of Rain Fall and Time (in min)
[I-Intensity of Rain fall mm/hour]

Alternatively, one hour duration storm intensity may be converted into any duration intensity using the following formulae given in IRC: SP:13.

$$i = \frac{F}{T} \quad \frac{(T+1)}{(t+1)} \qquad \text{.......Eqn. 1}$$

Where

i = Intensity of rainfall within a shorter period of 't' hours within a storm.

F = Total rainfall in storm in cm falling in duration of storm of 'T' hours.

t = Smaller time interval in hours within the storm duration of 'T' hours.

6.6.1 It is also added that as per practice being followed in most of the metropolitan cities, the calculation of runoff is being carried out using hourly rainfall intensity for a return period of one to two years. This is primarily for simplicity of calculations. However, for a large drainage system, it is recommended that calculations be carried out on the basis of detailed analysis as the efforts may be directed towards the saving in cost for the design of the drainage system.

6.7 Rational Formula for Estimating Peak Run-Off Rates

For small water sheds not exceeding 50 km^2, as is the usual case for urban drainage system, the Rational method is widely used for estimating the peak run-off rates. The formula is

$$Q = 0.028\,PAI_c \qquad \text{......Eqn. 2}$$

Where,

Q = Design peak runoff rate in cum/sec.

P = Coefficient of run-off for catchment characteristics.

A = Area of catchment in hectares.

I_c = Critical intensity of rainfall in cm per hour for the selected frequency and the duration.

6.7.1 The coefficient of runoff (P) is the portion of precipitation that makes its way to the drain. Its value depends on a large number of factors such as permeability of the surface, type of ground cover, shape and size of catchment area, the topography, the geology, initial state of wetness and duration of storm. The value of 'P' commonly adopted for used in Rational Formula is given in **Table 6.1**.

6.7.2 The values of coefficient of run off for different types of surfaces is given in **Table 6.2**.

Table 6.1 Values of Co-efficient of Run-off

Sl. No.	Description of Surface	Coefficient of Run-off (P)
1)	Watertight pavement surface (concrete or bitumen), steep bare rock.	0.90
2)	Green area (Loamy)	0.30
3)	Green area (Sandy)	0.20
4)	Unpaved area along roads	0.30
5)	Lawns and parks	0.15
6)	Flat built up area with about 60 percent area impervious	0.55
7)	Moderately steep built up area with about 70 per cent area impervious	0.80

6.7.3 If any change is expected in the land use pattern in the contributing area during the life time of the drainage system, consideration for same should also be taken in the design. It is a common practice that the run-off coefficient for the whole area is derived after estimating or ascertaining the proportion of the various surfaces to the whole area. Some common figures adopted for coefficient of run-off are given in **Table 6.2.** It is also to be remembered that run-off coefficient tends to become larger as rain fall continues due to filling of depressions in impervious surfaces and soaking of the upper layers of exposed soil.

Table 6.2 Co-efficient of Run-off for Various Surfaces

Sl. No.	Description of Surface	Coefficient of Run-off
1)	Most densely built up areas	0.7 to 0.9
2)	For adjoining area to built up areas	0.5 to 0.7
3)	Residential areas	0.25 to 0.5
4)	Sub-urban areas with few building	0.10 to 0.25

6.8 Hydraulic Design

6.8.1 *Design of drain section*

Capacity of the drain is normally designed using Manning's formula

$$Q = (1/n)\, AR^{2/3}\, S^{1/2}$$

and

$$V = 1/n\, R^{2/3}\, S^{1/2}$$

Where

Q = discharge in cum/sec

V = Mean velocity in m/sec

n = Manning's regosity coefficient

R = Hydraulic mean radius which is area of flow cross-section divided by wetted Perimeter

S = Gradient of drain bed

A = Area of flow cross section in m^2

6.8.2 The coefficient of regosity for various surfaces is given in IRC:SP:42 may be referred to. Some average values are, however, indicated in **Table 6.3** for general guidance.

Table 6.3 Co-efficient of Regosity for Type of Surfaces

	Type of Surface	Value of n
i)	Brick pitched drain	0.017
ii)	Plastered brick surface	0.015
iii)	Plastered brick surface with neat cement finish	0.013
iv)	Concrete pipes upto 600 mm dia	0.015
v)	Concrete pipes above 600 mm dia	0.013
vi)	Dry rubble masonry	0.033
vii)	Dressed ashler surface	0.015
viii)	Dry stone pitching	0.020
ix)	Kutcha drain	0.025

6.8.3 While deciding the drain sections, it is not enough that they are sufficient to carry the required discharge, guidelines given **Table 6.4** are also required to be kept in view.

Table 6.4 Minimum and maximum velocities

		Minimum m/Sec.	Max. m/Sec.
i)	Internal drain (brick pitched or plastered)	0.45	1.5
ii)	Intercepting and main drains (brick pitched or plastered)	0.75	1.5
iii)	Pipe drain (running full)	0.75	1.8

To ensure self cleaning of the drain, a minimum velocity of 1.5 m per second may be desirable. However, this may require installation of concrete drains or paved drains.

6.8.4 *Minimum free board*

	Drain size	Free Board
i)	Beyond 300 mm bed width	10 cm
ii)	Beyond 300 mm & upto 900 mm bed width	15 cm
iii)	Beyond 900 mm & upto 1500 mm bed width	30 cm

For larger drains the free board shall be higher upto 90 cm depending upon the discharge.

6.8.5 *Minimum section of drain*

It should be possible to clean the drains periodically using a spade. Accordingly, it is recommended that minimum width of a drain should not be less than 250 mm. In case of pipes the minimum diameter should not be less than 450 mm.

6.8.6 The effective section of the drain carrying design discharge should be considered below the bell mouth pipe so that there is no back flow of water on to the road.

6.8.7 *Channel shapes*

The usual channel shapes are:

i) Parabolic

ii) Trapezoidal

iii) Rectangular

iv) Triangular or V shaped

The parabolic profile is considered to be the best for hydraulic flow but its actual construction and maintenance is difficult. The V shaped drain is not very popular in urban areas as its desilting is difficult. The trapezoidal and rectangular sections are easy to construct and are considered most suitable. In urban areas all drains passing through built up area and near to bus stand, crossing etc. should preferably be covered so that the drains are not used as dust-bins. Even if the drains cannot be covered in the initial stage due to economy reasons provision should be available for covering it at a later stage. However, it should be kept in mind that pipe drains are difficult to desilt and maintain.

6.8.8 *Economical sections (for lined drains)*

As far as possible, for obtaining economical sections, the relation between bed width and depth shall be as follows:

i)	Rectangular	b = 2d
ii)	Trapezoidal	b = 0.82d (1:1 side slope)
		b = 1.24d (1/2:1 side slope)

For main or trunk drains the side slopes should be 1:1 or ½:1 depending upon nature of soil and availability of land.

6.8.9 *Cunetts and cross slope in bed*

All main drains wider than 3 m shall be provided with a central cunett for dry weather flow. If the dry weather flow can be estimated it should provide for the same. Some municipal authorities, based on experience, provide for 6 to 7 percent of peak flow. A cross slope of 1 in 20 to 1 in 30 shall be provided in the bed towards the centre of the cunnet.

6.8.10 *V Poles*

One important structural aspect of drain will be to provide weep holes in the bed of all main drains where the height of water table is expected to be above the bed level of the drain.

6.8.11 *Silt trap*

A suitably designed silt trap in the form of tank, which can be maintained easily shall be constructed at all the inlet points of every covered drain and also provided with vertical grating in order to avert entry of floating material into the drain.

7 SUB SURFACE DRAINAGE - DIFFERENT TYPES OF FILTER MATERIAL

7.1 Subsurface water in the granular layers or in the subgrade of a pavement may harm the road in different ways.

a) The presence of water reduces subgrade strength. The strength of granular bases/sub-bases is strain dependent and poor strength in subgrade affects the performance of top granular layers also.

b) Heavy wheel loads may create pulsating water pressure resulting in internal erosion and ejection of materials through cracks and joints. This, coupled with movement of subsoil water, changes the arrangement of fine to coarse material and aggregates in the structure resulting in weakening granular bases, cement treated bases and stabilized layers.

c) Absorption of water in the filler material, which may not be fully non-plastic, may seriously undermine the load support characteristics of the layer.

d) Free water in bituminous pavements results in stripping of the binder leading to faster cracking and deterioration.

7.2 For design of subsurface drainage system, the source and quantum must be determined, and the ingress of water may take place from

a) Top i.e., surface infiltration of water through paved or unpaved areas,

b) Lateral seepage through shoulders and verges, and

c) Free water from a high water table or capillary action from a water table.

7.3 In most urban areas, the percentage of built up surface area is rather high and as such situations with problems of subsurface water may not be frequent unless the water table is unusually high and the subgrade soil is poor from point of view of drainage. Physical condition of nearby roads, presence of vegetation which usually occur in wet soils and the local experience helps in selecting area for detailed investigation. During detailed investigation, the following information is collected :

i) Rainfall data for the area and the design of storm water. This aspect has been covered in Chapter-6

ii) Assessment of ground water conditions. This is achieved by making boreholes, trenches and pits. Water levels and inflows should be carefully recorded at the time of excavation. Pumping tools can be used to establish the in-situ permeability of materials, and the rate of recoupment of ground water. For gathering information on water table using piezo-meters, understanding the location of various strata through study of bore log is essential. These are required to be installed in the strata which influence water table level. As such, these should never be installed at a predetermined depth but should be installed in the particular strata.

iii) Assessment of the soil properties, information in respect of soil classification. Atterberg limits and moisture content of soil at subgrade level and other levels in areas are made where water is present and collected.

7.4 Drainage of Surface Infiltration

7.4.1 Road surfaces, medians, shoulders and rainfall on higher adjoining areas are permeable and the precipitation invariably seeps down. Collection of water in potholes and undulations etc. also contributes to seepage cracks in pavement, particularly due to ageing, defects and joints also permit ingress of water into the road structure. For design purpose, the quantity of water which is required to be drained off is dependent upon the intensity of rainfall and the coefficient of infiltration or the infiltration factor. Commonly adopted ranges are

i)	Earthen shoulders	0.4 to 0.6
ii)	Bituminous pavement	0.2 to 0.4
iii)	Concrete pavements	0.3 to 0.4

7.4.2 The best way of drainage of pavement course is to provide and extend a specially designed sub-base layer upto the embankment slope face. In urban situations, this may not always be possible. In such a case, provision of a subsurface drain is made. The sub base layer and the subsurface drain should have sufficient capacity to carry the design discharge. Flow through sub-base layer, which is considered as saturated laminar flow, is calculated using Darcy's Law and the flow through pipes is calculated using Mannings formulae. The Darcy's Law given :

$$Q = KiA$$

Where,

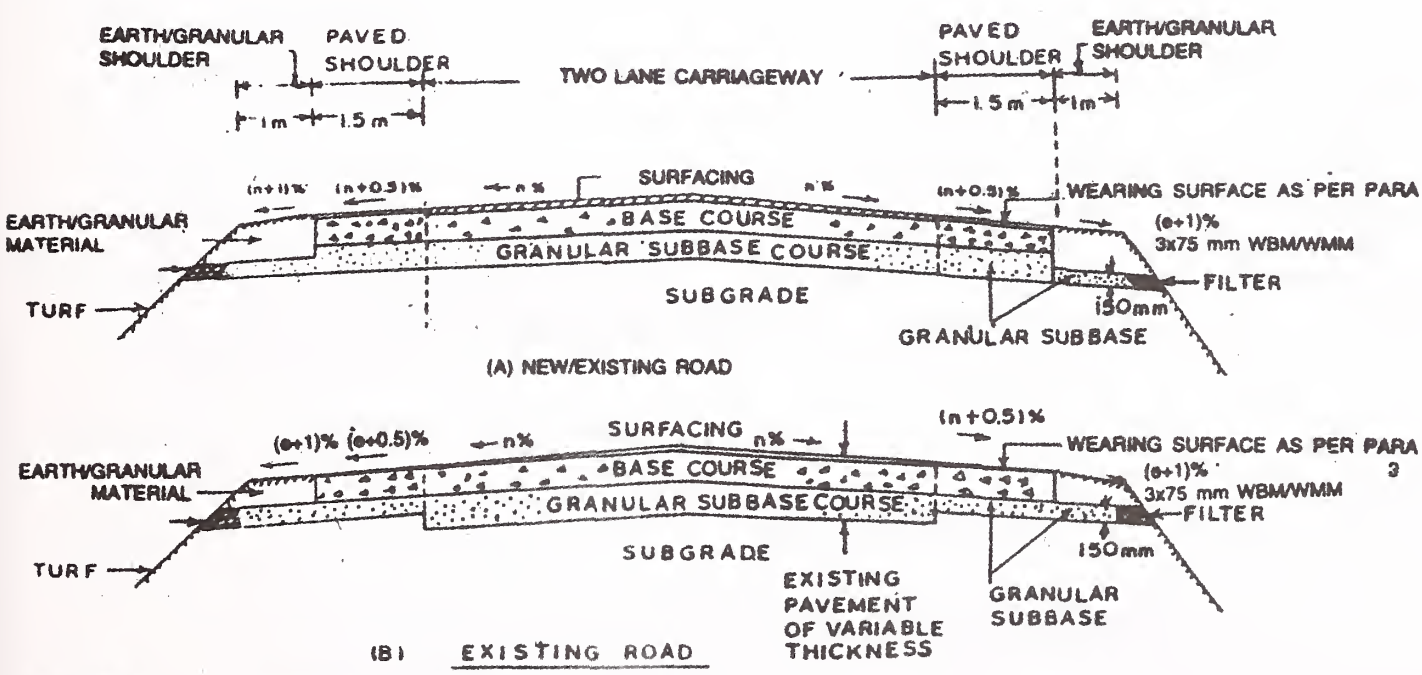
Q = Discharge in m^3/sec.

K = Coefficient of permeability in m/sec

i = Hydraulic gradient

A = Cross-section area in m^2 perpendicular to the direction of flow.

7.4.3 Sub-base and base should have self draining provisions by extending granular drainage layer fully over the road formation width (Ref. **Fig. 7.1**). In addition, proper cross fall to the drainage layer should be provided to guard against any sluggish flow. Road subgrade should also be provided with a cross fall appropriate to the material with which it is built so that there is no accumulation of water on top of the subgrade due to sluggish flow at that level. As a general rule, the lower pavement layer should be more permeable than the upper one. In case of existing pavements, where such situation may become unavoidable from other considerations, the overlaid layer having larger voids should be drained off laterally to avoid interfacial drainage problems and premature failure of the overlaid layer. Typical arrangement of drainage of pavement is shown in **Fig. 7.2.**



NOTATION
e = CROSS FALL (CAMBER) OF PAVEMENT.
WBM = WATER BOUND MACADAM
WMM = WET MIX MACADAM.

NOTES:

1. **(e+1)% CROSSFALL SHALL NOT BE LESS THAN 2.5 TO 3% ON GRANULAR SHOULDER AND 3 TO 4% ON EARTH SHOULDER – STEAPER VALUES SHALL BE USED FOR RAINFALL EXCEEDING 150 CM PER YEAR.**
2. **ON SUPERELEVATED SECTIONS THE SHOULDER SHOULD HAVE SAME CROSSFALL AS THE PAVEMENT**

Fig. 7.1 Typical Cross-section of Paved Shoulders

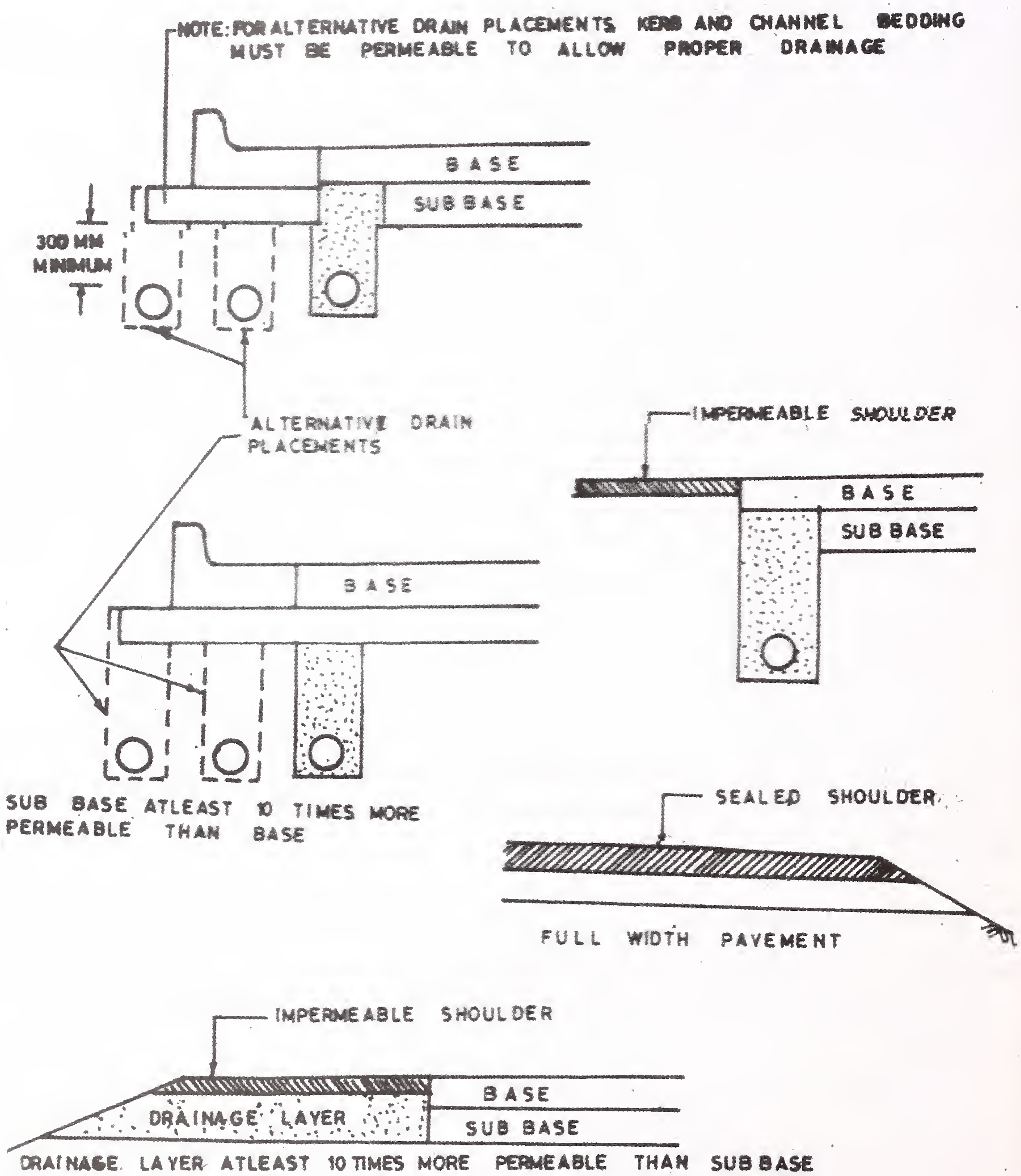


Fig. 7.2 Examples of Satisfactory Pavement Drains

Typical examples to determine permeability requirement of drainage layers and the quantity of flow are given below:

1) To determine permeability requirement of drainage layer to dispose off infiltration of water.

Given: The design rainfall intensity of a city is 5 cm/hr. The pavement camber is 3 percent and the longitudinal gradient is 4 percent, coefficient of infiltration is 0.3. It is proposed to utilize a permeable layer 250 mm thick to carry this water to subsoil drainage trench on the low side of the pavement.

Quality of water entering the pavement per meter length of carriage way

= 0.05 x 1 x 1 x 0.3 = 1.5 x 10–2 m^3/hour.

The camber of 3 percent and longitudinal gradient of 4 percent gives a resultant slope of 5 percent at an angle of about 37^0 to the centre line. The width of longitudinal 1m wide pavement along the line of maximum slope is therefore, 0.6 m.

Darcy's equation can be written as:

$$K = \frac{Q}{iA} = \frac{1.5 \times 10\text{-}2}{0.05 \times 0.25 \times 0.6} = 2 \text{ m/hr}$$

Or, required K = 5.55 x 10^{-4} m/sec.

2) To determine quantity of water intercepted by a formation drain provided across water charged permeable layer.

Given: Thickness of permeable layer is 2.0 m and is on a 15 percent slope. The permeable strata are silty sand having maximum permeability of 1.8 x 10^{-5} m/sec.

or Q = 1.8 x 10-5 x 0.15 x 2

= 6.4 x 10^{-6} m^3/sec. per m length of the drain

Thus, the formation drain and the pipe should be of sufficient capacity to cater for this discharge and any particular section of the drain should be designed for cumulative discharge upto that point.

7.5 Drainage of Subsurface Water

7.5.1 Darcy's law is applicable for subsurface flow of water. However, in actual practice one encounters soil or rock formations which are highly heterogeneous and have anisotropic permeability's. Fissures, joints, faults and bedding planes in soils and rock structures may give quite different properties and misleading ground water conditions. Applications of theoretical models to complex natural situations can lead to errors in estimation of quantity of flow and flow conditions. For these reasons field observations and measurement is the best guide. Also, interpretation of observations should be done by those who have geotechnical skills. In some cases, it may be desirable to arrive at the solution through trial either before or during early construction phase of a project by measuring the flows and water table. The depth of drain is increased or additional provision is made at closer spacing. It may also be necessary to have field or laboratory determination of permeability coefficients in the selection of pavement, shoulder, surfacing and drainage materials. As a general guide permeability ranges are given in **Fig. 7.3.** For a successful design using range of permeability

for a given material, the highest permeability value should be used when the material is to act as a barrier and the lowest value used when the material is being used to allow water to pass through.

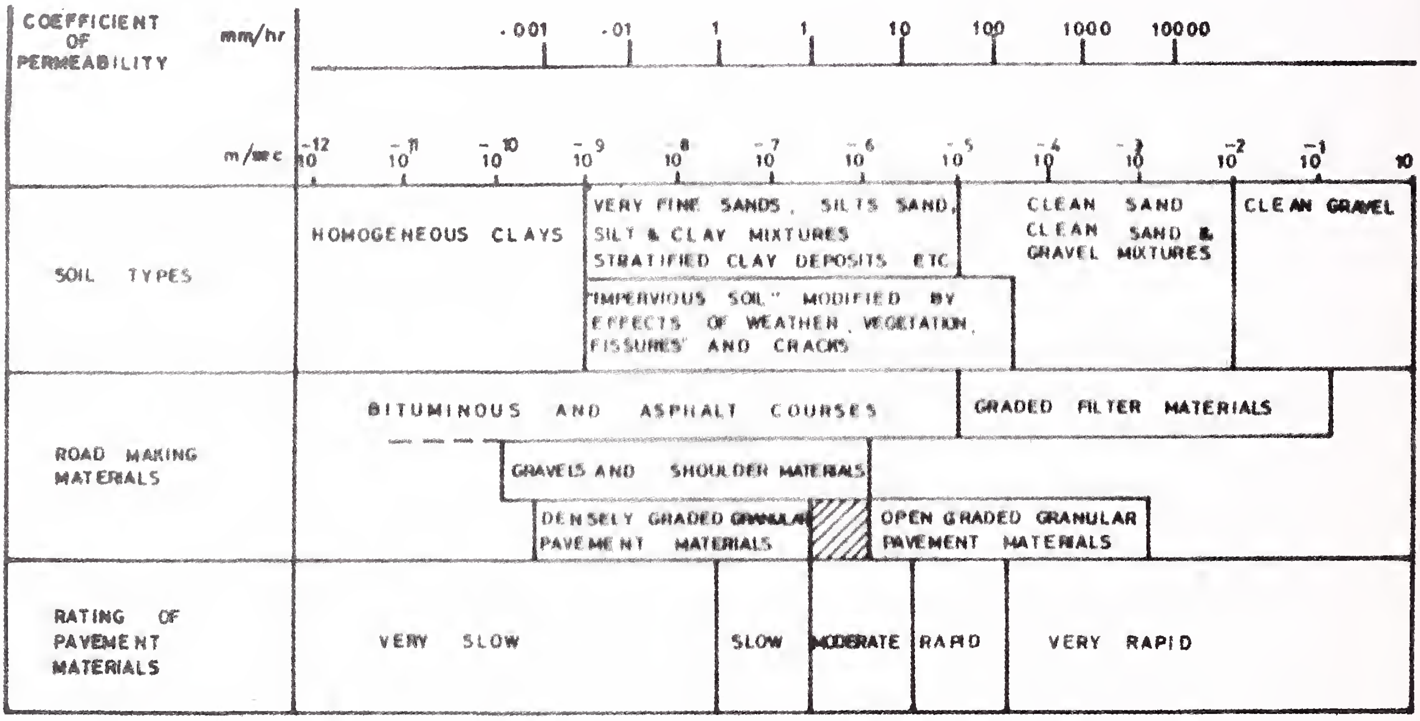


Fig. 7.3 Permeability Ranges

Some typical arrangements indicating use of formation drains and drainage blanket is shown in **Fig. 7.4.** The drainage can be effected by installation of solid pipes with open joints, perforated pipes and the like surrounded by free drainage material or the filter. The filter material is required to prevent fine soil particles from flowing into the system, at the same time it should have required degree of permeability for drain off the required quantity of water. Also, the filter material must be more permeable than the surrounding material and stable under flow situations so as not to flow into perforations or joints in drainage pipes.

7.5.2 *Aggregate filters*

A properly designed and installed aggregate filter should be able to retain soil and prevent the movement of soil particle, thus eliminating piping potential. Properly, designed aggregate filters ensure that there are no large voids within the filter and particularly at the soil filter interface of a subsurface drainage structure. A single component aggregate filter may be used to protect relatively coarse soils whereas drainage through fine soils usually require a multi-layered aggregate filter. A multi-layered filter consists of a fine aggregate gradation which retains the natural soil particles at their original positions and a coarser filter aggregate which prevents particles of the fine aggregate filter from migrating into the perforations of a drainage pipe or granular water transport medium. **Fig. 7.5** shows, in a schematic way, the effect of a properly designed filter and improper filter. A MORTH Specification for Road and Bridge Works (Fourth Revision) gives the grading requirement for filter material and also the grading requirements for aggregate drains. These are reproduced as **Tables 7.1 and 7.2** for

ready reference. It must be remembered that if the aggregate gradation is too coarse, the gaps and voids at the soil aggregate interface may be so large that the adjacent soil particles will not bridge or be retained. However, if the gradation is too fine, insufficient water flow may result in build-up of hydrostatic pressure. Theoretical gradation of filter material is also possible based on empirical relationships between the particle size of soil and the filter using filtration as well as permeability criterion.

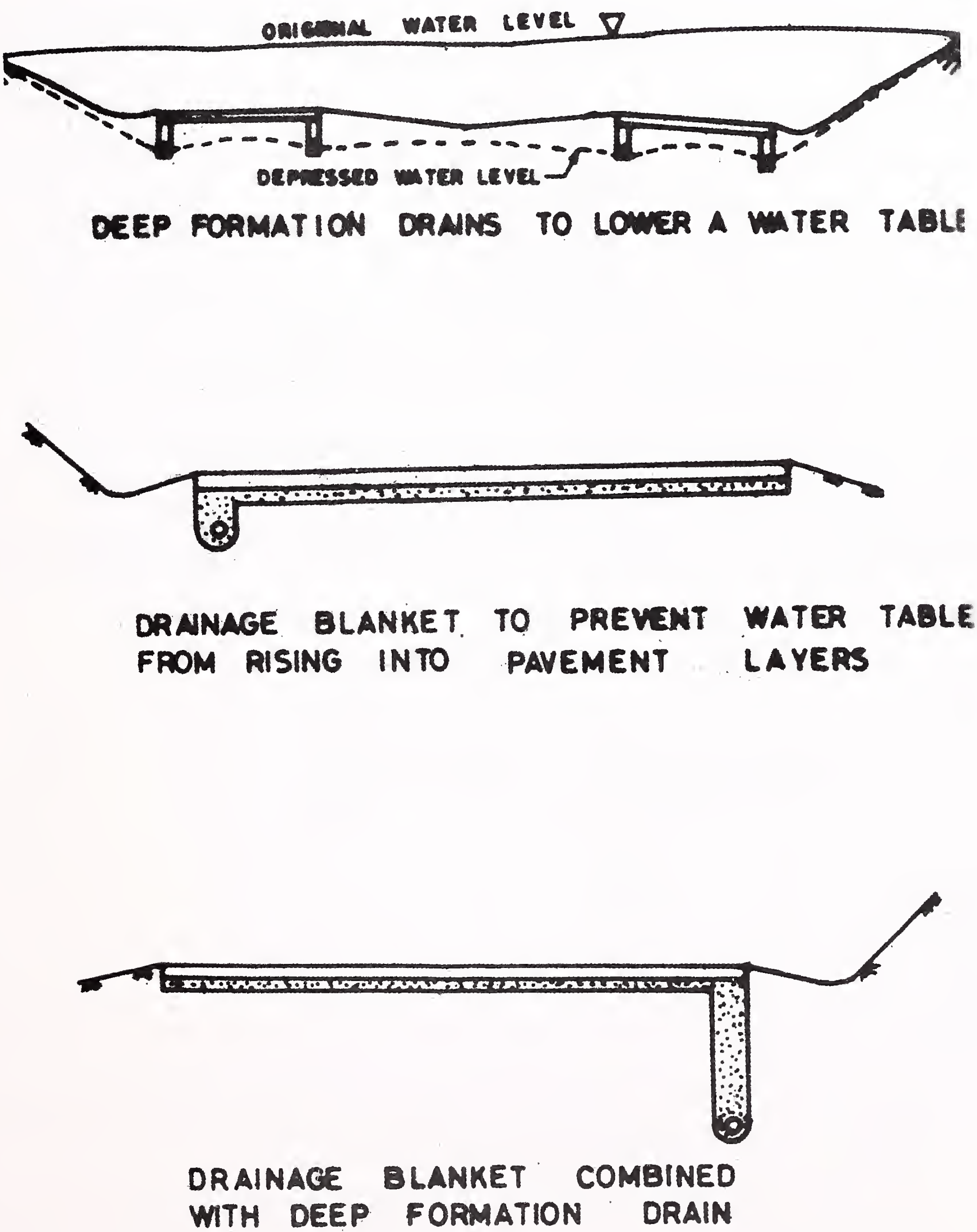


Fig. 7.4 Techniques for Lowering a Water Table

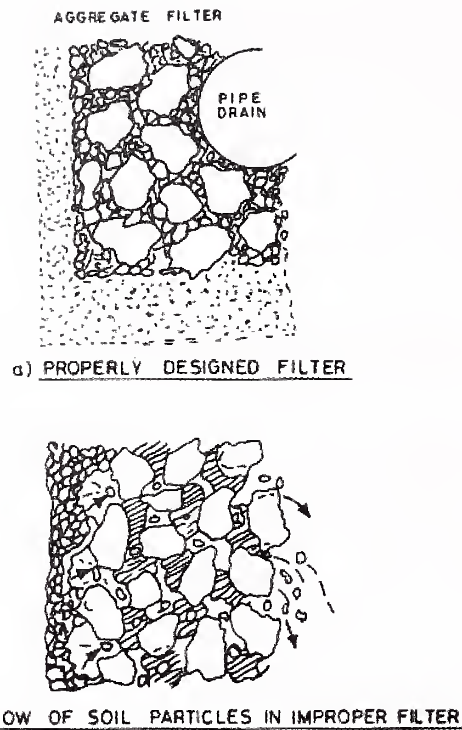


Fig. 7.5 Mechanism of Flow Through Properly Designed Filter

Table 7.1 Grading Requirements for Filter Materials

Sieve Designation	Percent Passing by Weight		
	Class I	Class II	Class III
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	58-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-5
1.4 mm	59-96	-	0-5
710 micron	35-80	6-18	-
355 micron	14-40	2-9	-
180 micron	3-15	-	-
90 micron	0-5	0-4	0-3

Note :

1) When the soil around the trench is fine grained (fine silt or clay or their mixture) then Class I grading, when coarse silt to medium sand or sandy soil then Class II grading and when gravelly sand then Class III grading should be adopted.

2) The thickness of backfill material around the pipe should not be less than 150 mm. considering minimum diameter of the pipe as 150 mm, width of the trench should not be less than 450 mm.

Table 7.2 Grading Requirements for Aggregate Drains

Sieve Size	Percent Passing by Weight	
	Type A	Type B
63 mm	-	100
37.5 mm	100	85-100
19 mm	-	0-20
9.5 mm	45-100	0-5
3.35 mm	25-80	-
600 micron	8-45	-
150 micron	0-10	-

7.5.3 *Fabric Filters*

Filter fabrics or Geotextiles are generally manufactured from polyethylene or polypropylene or similar fibers, either woven or non-woven in variety. Specification of Geotextile has been covered in MoRT&H Specifications for Road & Bridge Works and has not been repeated here. For subsoil drainage system bio-degradable fabric filters are not used as their life span is very short. Geotextiles eliminate the need for aggregate filters. The fine pore size and high permeability of these filters make one filter suitable for protecting a broad range of soil gradations. Also, such filters are available with varying pore sizes and permeability properties so as to meet the need of nearly all subsurface drain designs. Some typical example of use of fabrics as filters is shown in **Fig. 7.6**.

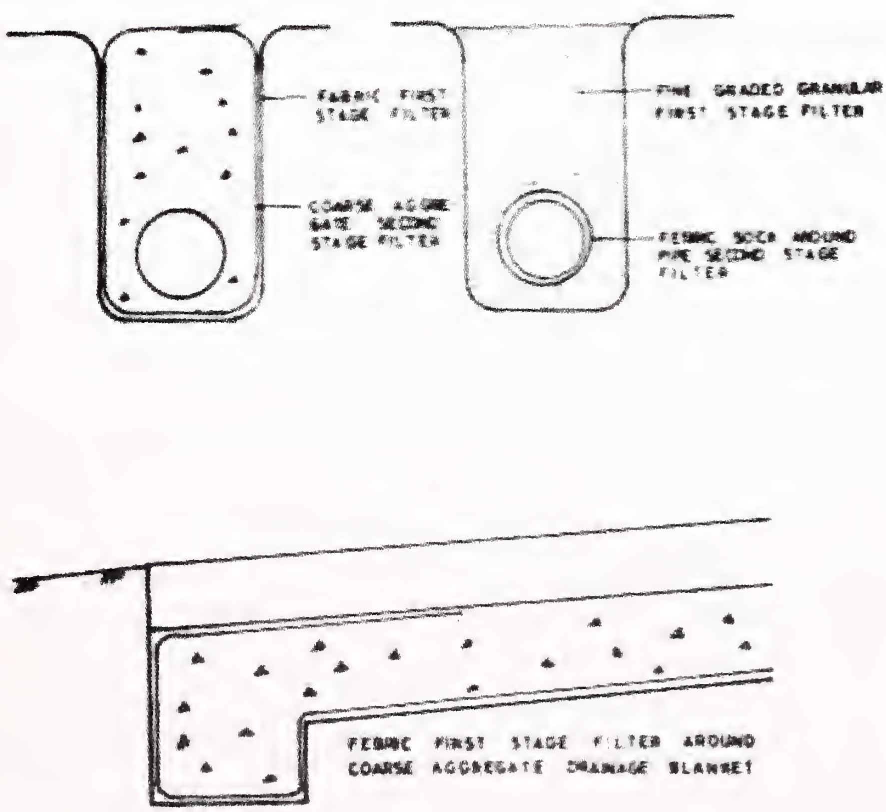


Fig. 7.6 Uses of Fabrics as Filters

Briefly, there are three basic requirements on the elements of filter criteria for drainage fabrics. These are:

a) Retention (of interface soil) Ability

It is specified by $\frac{EQS}{D_{85\ soil}} < 3$

Where, EQS is the equivalent opening size and is defined as the size of standard sieve having opening closest in size to the filter fabric and is determined by sieving glass beads through the fabric D85 soil=nominal diameter of soil particles for which 85 percent of the soil gradation is finer – determined by grain size distribution analysis.

b) **Permeability:** The permeability of the fabric filter should be substantially greater than that of the protected soil.

For proper flows:

$$K\ fabric > 10\ K\ soil$$

Where K is the coefficient of permeability

c) **Clogging Resistance:** The clogging behavior of a geotextile should be evaluated in a test that simulates actual use condition. One such test is to make up a slurry of the soil to be filtered and filter it through a sample of fabric. If the finest particle pass through without clogging the fabric and the rate of flow is satisfactory. The fabric may be considered to perform adequately as a filter.

7.5.4 *Subsoil water drainage system*

The purpose of the subsoil drainage is to collect the water from its source and ultimately dispose off to a place where it can do no harm to the road. It consists of filter, the pipe inlets, intermediate pits and the outlet marker pegs are also installed to indicate their location. A schematic diagram of the system is shown in **Fig. 7.7.**

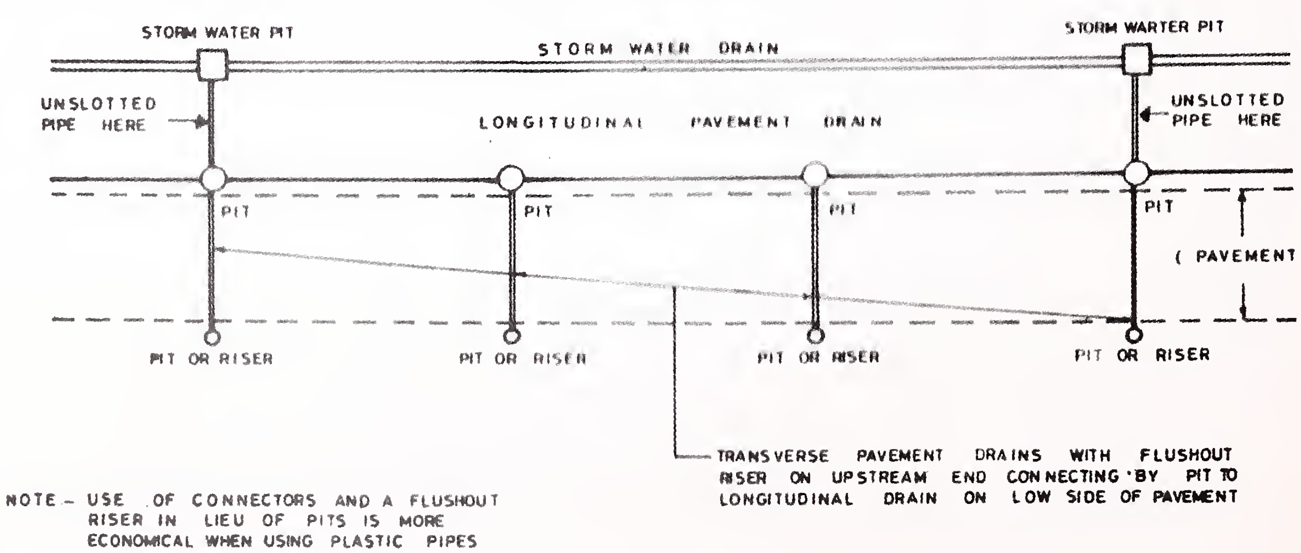


Fig. 7.7 Plan of Pavement Drainage System

Use of Subsoil Drainage for Special Locations

In urban areas utility services usually run parallel to the road and in many cases, due to widening of roads they get buried below the pavement or the footpath. Due to large temperature variations particularly when the season changes and vibrations of the moving traffic, some of the joints of underground water supply pipe may leak leading to subsoil water conditions and damage to road. In such locations, subsoil water drainage arrangement should be made to safeguard the structural soundness of the road.

8 DISPOSAL OF ACCEPTABLE QUALITY OF STORM WATER

The adverse impact of development activity in urbanization with respect to storm water quality needs to be mitigated. In the present scenario of severely polluted storm water drains, first by discharge of sewerage water and secondly by polluted storm water, the discharge itself shall be regulated. Sewerage drains and their content shall strictly be forbidden from entering storm water drains. This can be achieved by providing cutoff drains all along and lead to storage tank & this sewage water can be treated through STP & used for watering plants, medians & excess can be lead to main SWD.

After negotiating this impediment, the next pollutant from storm water itself needs to be managed. There shall be a programme of self-designed storm water pollution prevention plan. Some sort of regulation shall be in place for setting forth practices, procedures and objectives for controlling storm water quality in urbanized locations.

In order to effectively remove urban pollutants from storm water many methods can be adopted.

Existing open tanks or wet ponds which are nothing but retention ponds, serves both the purposes of controlling the volume of runoff and treating the runoff for pollutant removal. They will act as permanent storing pool during dry weather. These wet ponds can have aesthetic value; can be used for recreational purposes and also as emergency water supply. Over flow from the pond is released by hydraulic outlet devices designed to discharge flows at various elevations. Regular desilting, especially removal of finer particles from bed of tanks in addition to pollutants will keep the detention/retention facility always ready to take next batch of storm water of good quality.

In the urban scenario where parking lots, bigger complexes and other structures which discharge large quantity of pollutants along with storm water needs to install filter and oil-grit separator arrangement so that drained out water shall be free from pollutants **Fig. 8.1** shows oil and grit separator in three chamber system. First chamber traps sediments, second one oil separation chamber and the final one for letting out cleaned storm water into the drainage network. This will improve the quality of water let into the drainage network.

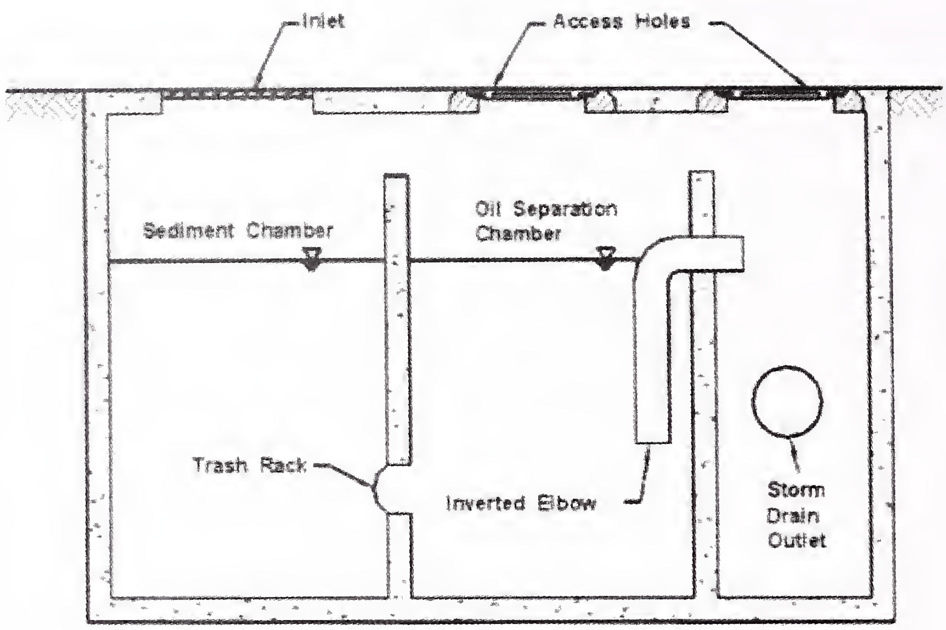


Fig. 8.1 Oil and Grit Separator in Three Chambers

The sewer water can be prevented from flowing into storm water system by providing cutoff drains

Segregating Sewer and storm water drainage systems

The segregation of sewer water flowing into storm water can be achieved by proving cutoff drains on both sides, all along primary and secondary drains. The sewer discharge can be linked to cutoff drains which ultimately connected to treatment plant or away from the city/ town See **Fig. 8.2**.

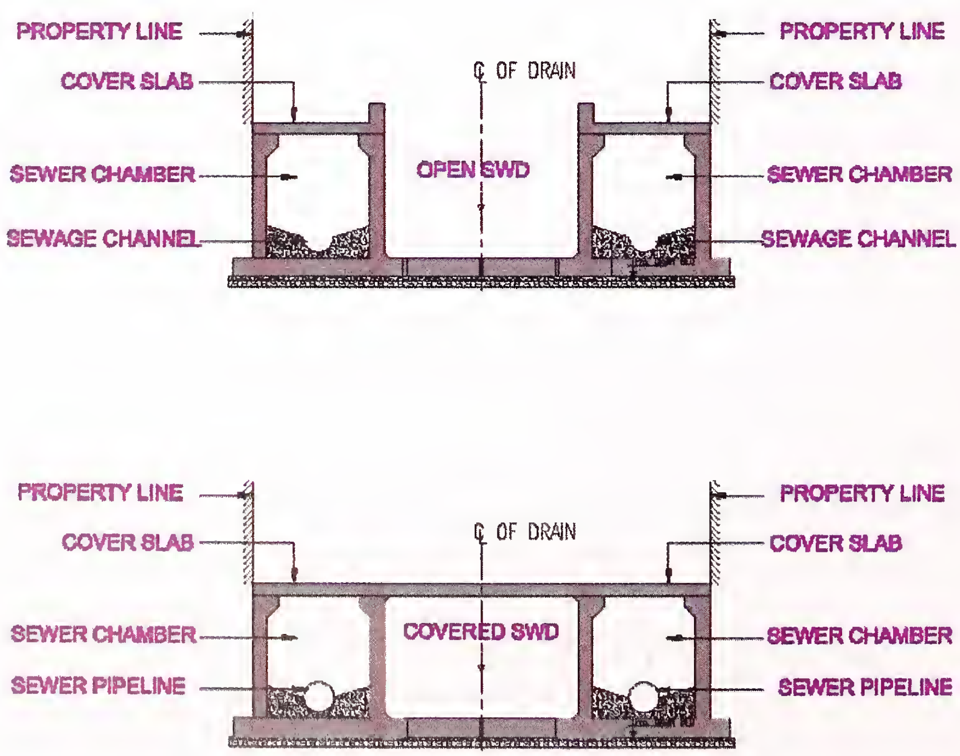


Fig. 8.2

Managing Water quality for health of ecosystems and human consumption : Monitoring quality of water flowing into the drainage channels or nallas is to be ensured for health of ecosystem and human consumption. (Stricter norms for solid waste disposal, industrial effluent control and any illegal discharge of waste into the drainage network by providing cut off drains as above).

Working open space network : Designing of open space systems along drainage corridor based on ecological value, planning for preserving and enhancing them. These could be used for eco mobility (Pedestrian and NMT movement) or as a city level park system with leisure trails and recreation zones.

To protect the existing water ways

To formulate guidelines for design, construction, operation and maintenance of the system.

Poor Drainage results in losses, direct and indirect in the form of damaged roads, reduced serviceability and serious health hazards to general public. Greater awareness on the subject is visible and importance of planning, organization, fund allocation and monitoring is taking place among urban conglomerates in recent times in the Country. Government is according greater importance for urban drainage of late and considerable funds are allocated to set right the perennially pending anomalies. Serious efforts are made towards identification and separation of sewerage drains and storm water drains. Immediate and all out efforts are required to separate these two drains or else environment will seriously and permanently be damaged leading to urban catastrophe. This will be important and serious issue for environmentalists.

Under no circumstances sewerage shall be allowed to flow in storm water drains in any part of urban area.

9 STORM WATER DRAINAGE OF SPECIAL LOCATIONS

The special locations in urban scenario for drainage will normally be:

9.1 Flyovers and bridges

9.2 Drainage at foot of flyovers

9.3 Vehicular subways

9.4 Rotaries

9.5 Retail outlets

9.6 Drains underneath the carriageway

9.7 Intersection

9.1 Drainage of Flyovers and Bridges

The entire rain water on the carriage way of flyover shall be drained though efficient piping network of rainwater of the area. Caution shall be exercised not to allow straight drop of water

from flyover to road surface below, which results in disruption of traffic and damage to road pavement. The rain water on flyover, which has to be above road is drained through either down take pipes or pipes embedded in the piers into series of network of rainwater harvesting system of the area and overflow can then be directed to the drains. All such disposal systems shall blend well and aesthetically pleasing.

A schematic arrangement is shown in **Figs. 9.1 and 9.2.**

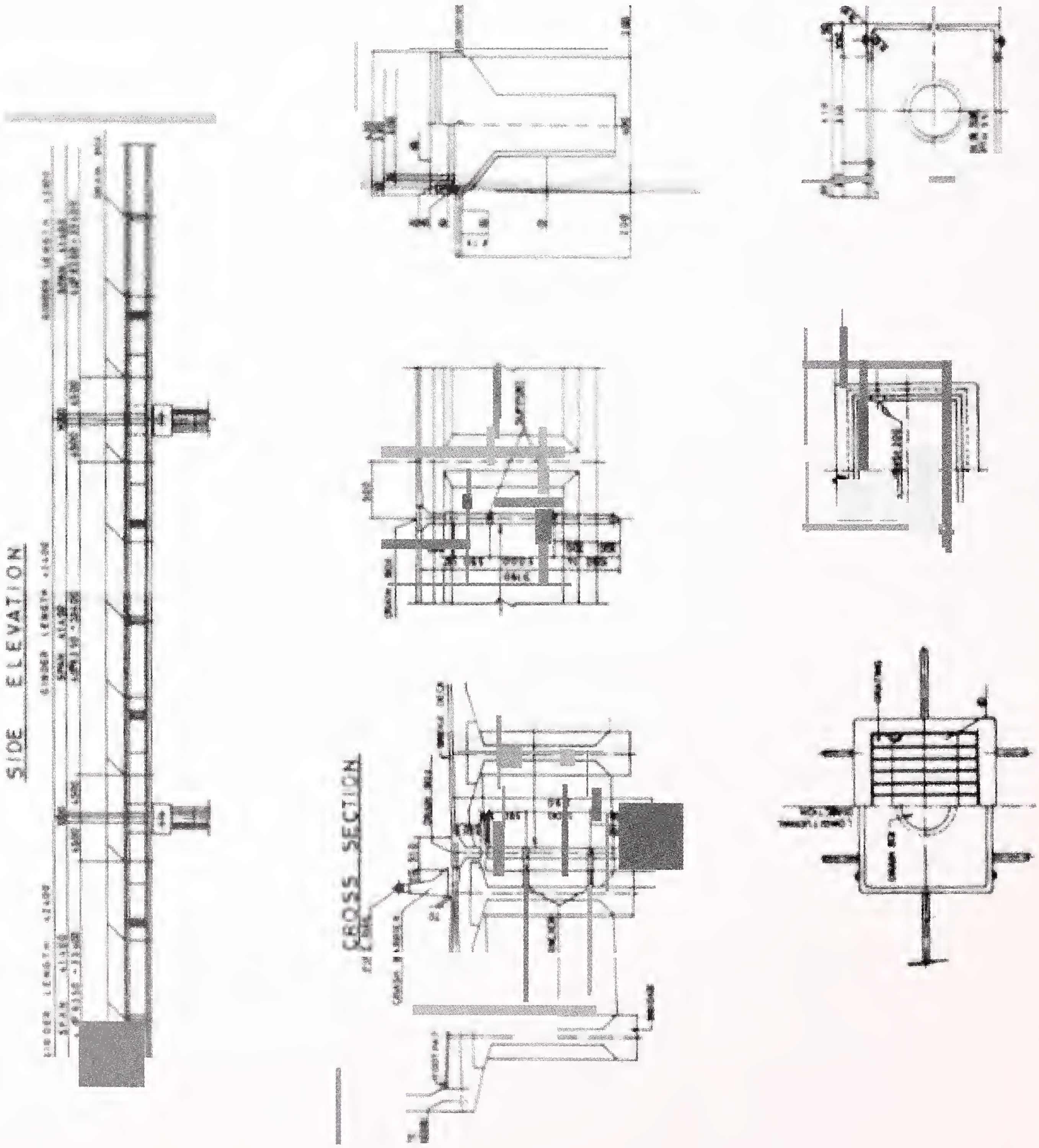


Fig. 9.1 and 9.2

9.2 Drainage at Foot of Flyovers

The longitudinal gradient of ramp of flyovers is usually upto 3 percent or even more and the cross slope will be about 2 percent. The majority of rain water flows rapidly in longitudinal direction rather than cross slope resulting in very large quantity of water reaching the valley curve area where it meets ground level road. This junction shall be provided with finger plate drain across the pavement. The valley junction shall be engineered in such a way, that even below road pavement shall have downward longitudinal gradient towards valley junction, so that entire rain water from flyover can be efficiently discharged into the drain at the edge. Then it can be directed to nearby stormwater management facility and overflow can be directed to the main drain which will stop the water from flowing directly to the road.

9.3 Vehicular Subways

Drainage of vehicular subways shall be efficiently planned at its conception stage itself. Most preferable system of drainage shall be by gravity. Entire surface drain of subway shall be taken to a lowest level and a suitable grating provided across full width of road. A typical subway drainage is shown in **Photo 9.3 (a) & Fig. 9.3 (b).** The grating shall have a disposal chamber which will collect the stormwater and dispose it to the nearby stormwater management facility like detention, retention ponds or open ground and overflow can be directly connected to the main drain. The lead off drain shall be preferably pipe drains with manholes at a maximum spacing of 30 m. In case of larger subways, two inlets can be provided at both ends of box-approach ramp junctions. The gratings shall be at least 10 m away from the deck to minimize ascending water during rains in the box portion.

Photo 9.3 (a) Drainage of Subway by providing a Grating Across the Full Width

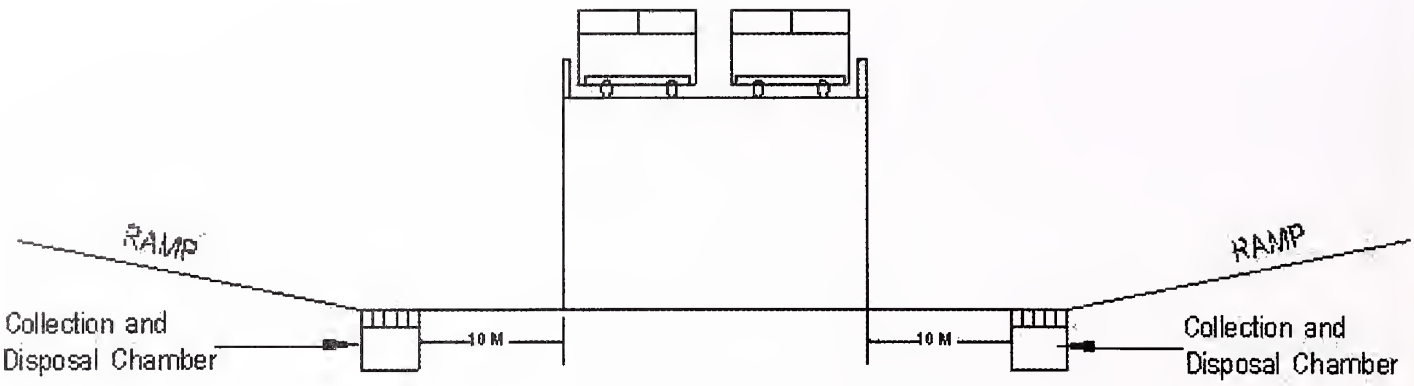


Fig. 9.3 (b) A Typical Cross-Section of Drainage in Subway

In case the drainage cannot be effectively discharged by gravity, necessary suitable pumping arrangement shall be made size of pumps shall be calculated based on drainage quantity with necessary sumps, debris filters etc.

9.4 Drainage of Rotaries

In urban situations, many intersections, particularly load traffic volume intersect sections are provided in the form of rotary.

In such locations, due to super elevation requirement water from a large area flows towards the center of the rotary. It is essential to this water and drains it to the main drainage system. A typical schematic arrangement is shown in **Fig. 9.4.**

Once the water is directed in the rotary, the overflow needs to drain off efficiently to the local drainage system. Minimum size of outflow from rotary shall be 600 mm width for ease of maintenance. If the site conditions permit outlets can be made multiple, which will reduce the depth of circular drain.

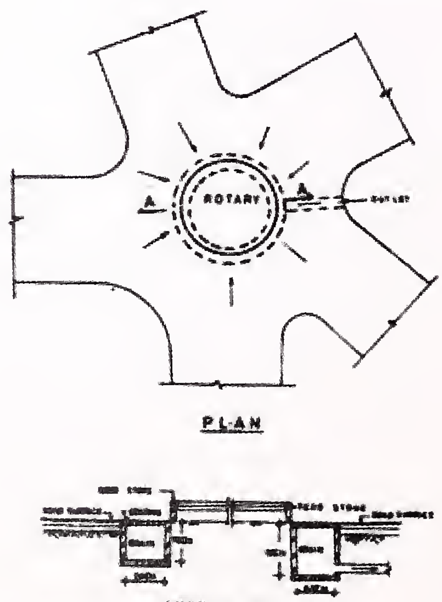


Fig. 9.4 Typical Drainage Detail at a Round About

9.5 Drainage of Retail Outlets

Many of the retail outlets or gas filling stations discharge water directly on to the pavement as in **Photo 9.5 (a)** resulting in rain water pooling on the carriageway till reaching nearest shoulder drain. Gratings shall be provided as in **Photo 9.5 (b)** at the approaches over the existing drain so that the rain water drains off effectively, without reaching the carriageway.

Photo 9.5 (a) Showing Discharge of Water Directly from MS/HSD Gas Outlet to Pavement resulting in Pooling of Storm Water on the Road Surface

Photo. 9.5 (b) Showing Grating Provided at a MS/HSD Gas Outlet for Effective Discharge of Storm Water

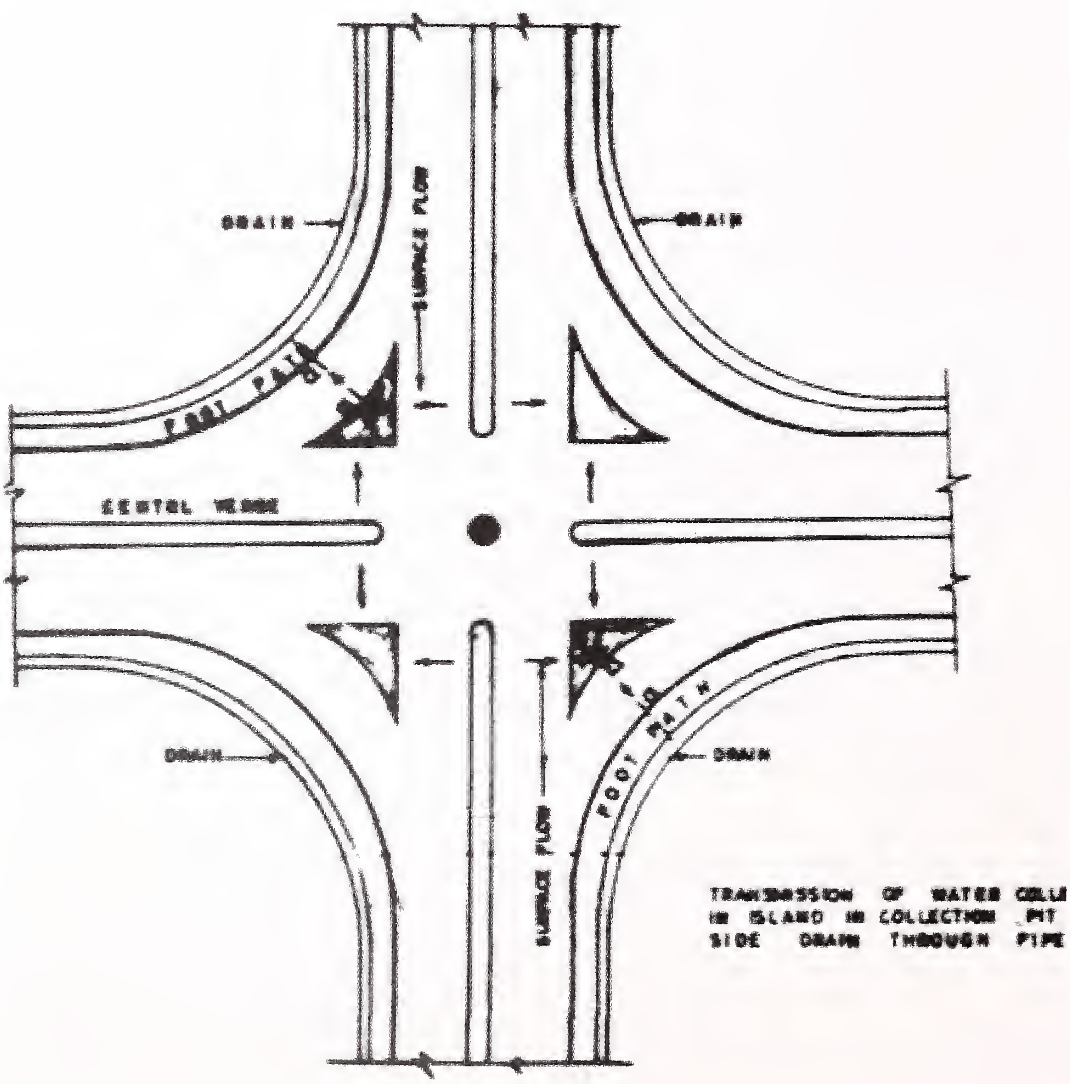
9.6 Drains Underneath the Carriageway

At many locations in urban limits, storm water drains run across the carriageway. The storm water can directly be drained through gratings designed appropriately.

9.7 Drainage at Intersections

Drainage at the intersections shall be well planned. The level of junction shall be slightly higher than the roads meeting, so that water can reach the traffic island at the corners, which already exist along respective roads. Any stagnation water at intersections would reduce the capacity of junction resulting in traffic jams and underutilization of junction. In the event of junction at lower level, the drainage shall be engineered in such a way that rain water shall be directed to this green traffic island and overflow can be connected to the main drainage system.

Schematic arrangement is shown in **Fig. 9.7(a)**



FLOW OF SURFACE WATER SHOWN BY →

Fig. 9.7(a) Drainage at Intersection

10 INFILTRATION OF STORM WATER, GROUND WATER RECHARGING, PONDS, AND RAIN WATER HARVESTING

10.1 In the recent past, rapid growth in the urban area has led to increase in asphalted/ concrete pavements and slabs or paver blocks for footpaths. Consequently the rain water runoff has increased and ground water recharge has declined causing more runoff on road surface and considerable flooding of secondary and primary drains finally discharged outside the city. Considering the depleting ground water, as much as 250 m below in some cities and towns, it is desirable to hold the water flowing away from city/town and charge the ground water within the city. This can be achieved among other systems by

i) Infiltration of storm water into the ground for recharging water table by retrofitting the ROW

ii) Providing Landscaping in round about's, medians, traffic channels, sidewalks (where the width is more than prescribed in IRC) and adoption of French drains

iii) Providing bore wells in the tertiary and secondary drains

iv) Use of secondary drains of porous layers & filter materials

v) Detention & Retention ponds

vi) Use for porous layers in pavement

vii) Perforated paving in Parking lots

viii) Rain water harvesting in buildings

10.1.i *Infiltration of storm water*

In the present scenario of depleted ground water in urban conglomerates, all storm water shall be efficiently utilized for the benefit of raising the existing ground water table. This can be achieved by redesigning the existing drainage cross-sections in such a way that storm water starts into ground at street level drain itself and continues through tertiary drains, secondary drains and primary drains.

Before the ultimate disposal of rain water all possible methods shall be adopted for ground water recharging. It shall be commendable if ground water recharging starts at initial point of road side drain of road itself. Storm water flowing into secondary and primary drains which shall also have ground water recharging facilities.

Infiltration of rain water, which is discharged from pavement surface, can be trapped by construction of infiltration-filter median drains, all along the pavement. The regular drains shall be located adjacent to infiltration drains, to facilitate pavement water from pavement will enter infiltration drains and incase of excess water will flow to regular drains. See **Fig. 10.1.i (a), 10.1.i (b), 10.1.i (c), 10.1.i (d)**.

Fig. 10.1. i (a) A Cross-Section Road with Recharging Drains

Retrofit Conditions for Existing Roads:

Retrofit road projects usually offer fewer options for flexibility. The following point should be considered while retrofitting existing streets for storm water management.

i) Draining of water from the road surface.

ii) Cost of rebuilding the street profile and underground infrastructure. Conforming to the existing street profile and identifying storm water solutions that work with this drainage condition is the simplest and most cost-effective approach to retrofitting a street. See **Fig. 10.1. i (b)**

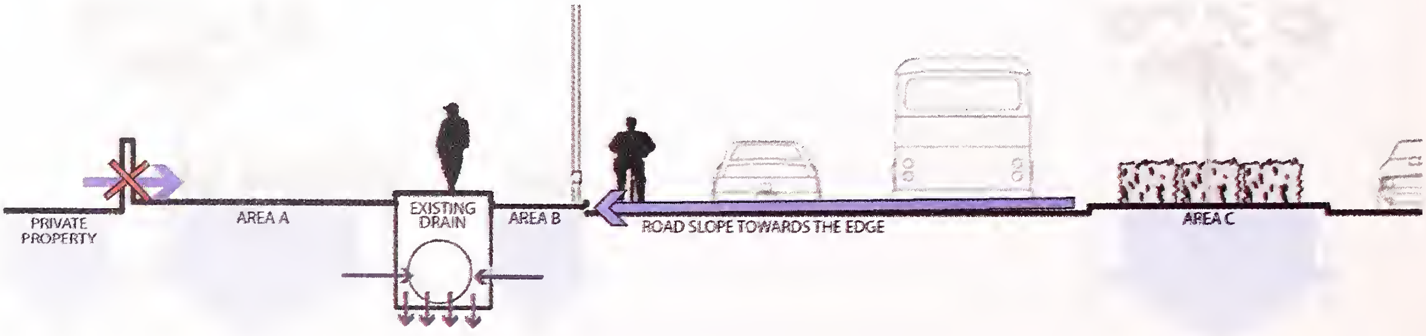


Fig. 10.1. i (b) Cross-Section of Typical Road Side Detail Showing a Retro Fit Option for Storm Water Management Facilities

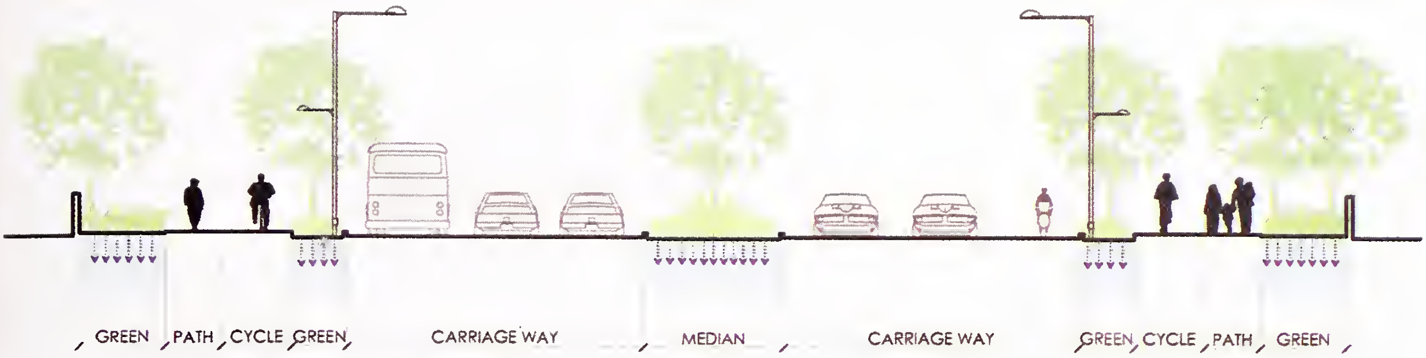


Fig. 10.1.i (c)

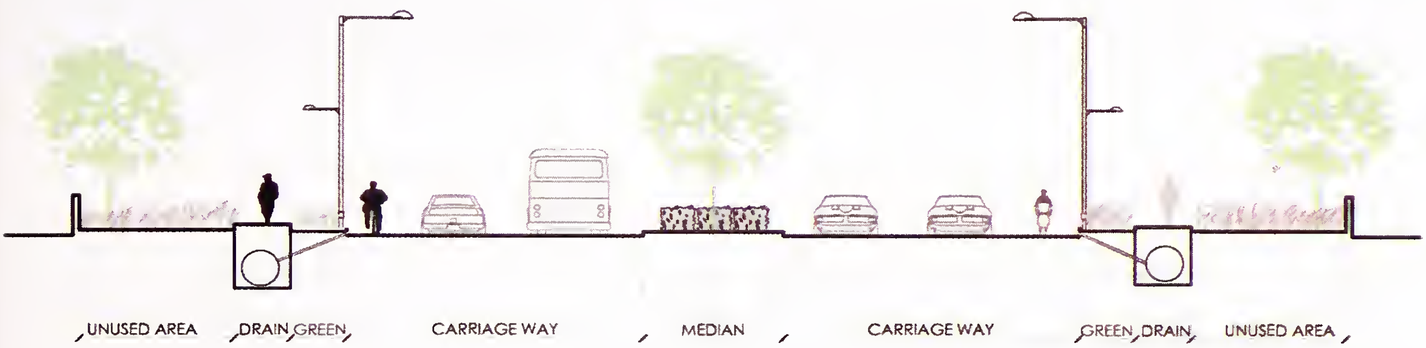


Fig. 10.1. i (d)

AREA A: This could be have storm water systems like filtration along with conveyance facilities depending on the width available, the water could infiltrate into the ground after passing through the infiltration process through different filter material layers as specified in Chapter-8 Section 4 and the excess water can be diverted to the main existing storm water drain.

AREA B: This area will capture water from the road and due to lack of space will convey the water to the main existing storm water drain after passing through the infiltration process through different filter material layers.

AREA C: This area will capture water falling on it and will filter the water to the ground water table after passing through the infiltration process through different filter material layers.

EXISTING DRAIN: Existing drain can be retrofitted to have soak pits and infiltration chambers at equal interval to let the storm water percolate to the ground water table at regular interval after passing through different filter layers as specified in diagram below.

ADJACENT PROPERTY: All the adjacent properties should retain the storm water into their property and have some recharge facilities or rainwater harvesting tank.

All the institutions, public parks, open recreational spaces, play-grounds, medians, water bodies etc. should be able to provide either detention or retention facilities so the excess storm water can be diverted to these areas for further ground water recharge.

A commercial street, where there is no green on site. As space is required for movement and parking, pervious paving in the parking area is provided as shown in **Fig. 10 (ii) (a) and (b)** above.

Fig. 10 (ii) (a)

Fig. 10 (ii) (b)

Conventional Road Section

Methods of investigation for estimating rates of surface water infiltration ground water levels and flows form an important part of the engineering of a drainage system. Use of self-draining materials and introduction of membrane has helped to control the migration of fine particles from sub grade specially while pumping, as relatively small migration of fines from sub-grade in to voids in the sub base can seriously reduce the capacity of the sub base to act as a lateral drain. The sub soil drainage shall be within design parameters. Highest precaution shall be exercised when water logged soil below sub grade may cause serious damage to the road crust.

Proposed Road Section

The primary advantage will be reduction in quantum of water at final disposal location. Secondary advantage will be recharging urban ground water which is depleting at alarming rate. Infiltration of storm water shall commence at street drains and shall be continued all along conveying system. Different suitable mechanisms shall be adopted for infiltrations, like providing filter mediums for certain length or providing filter bed at alternate junctions etc. Infiltration will also take place at detention and retention facilities where storm water can be controlled qualitatively and quantitatively. In the present state of rapid urbanization, this method will assume greater significance in the country's context as storm water needs to be conserved while it is made to runoff.

Disposal of acceptable quality of water: In the present scenario of rapid urbanization, the adverse impact of development activity needs to be mitigated. Urban storm water management practice has to be employed for storm water control with benefits and pollutant removal capabilities. Water quality practices shall be of acceptable standards while disposing off storm

water. Generally, urban storm water management practice shall adopt high pollutant removal for non-soluble particles pollutants such as suspended sediments. In the global scenario of recycling of available water, continuous disposal of contaminated water will seriously jeopardize the availability of potable water. In such circumstances, addition of recycled water to available fresh water is becoming a popular option in many of the countries and also in india. All possible efforts shall be made for continuous and constant removal of pollutants in the drainage system. All available open tanks shall be modernized effectively and utilized as detention and retention ponds and new additional ponds in the flow stream shall be created and added.

Urbanization of any locality and population needs well engineered surface and sub-surface drainage system. In the present day context of depletion of water table, the storm water drainage shall be effectively utilized for ground water charging. Water from the road flows to the road side drain through inlets and gratings. For effective drainage this should join the peripheral drains, which in turn should join the main or trunk drain for ultimate discharge to the natural drain or detention facility or retention facility. Storm water drainage, needs to take into account alignments, levels on ground and outfall levels. Existing drains pass through highly developed and thickly populated areas. As such, there may be a problem of availability of land for increasing capacity of drains, further. Also, the problem of availability of land, for effective disposal of storm water, may not be possible due to non-availability of further land.

If there is less space on road side, water can be taken through drain channel to nearby large green area or other conveyance system/harvesting system as shown in **Fig. 10.1 (ii) (c).**

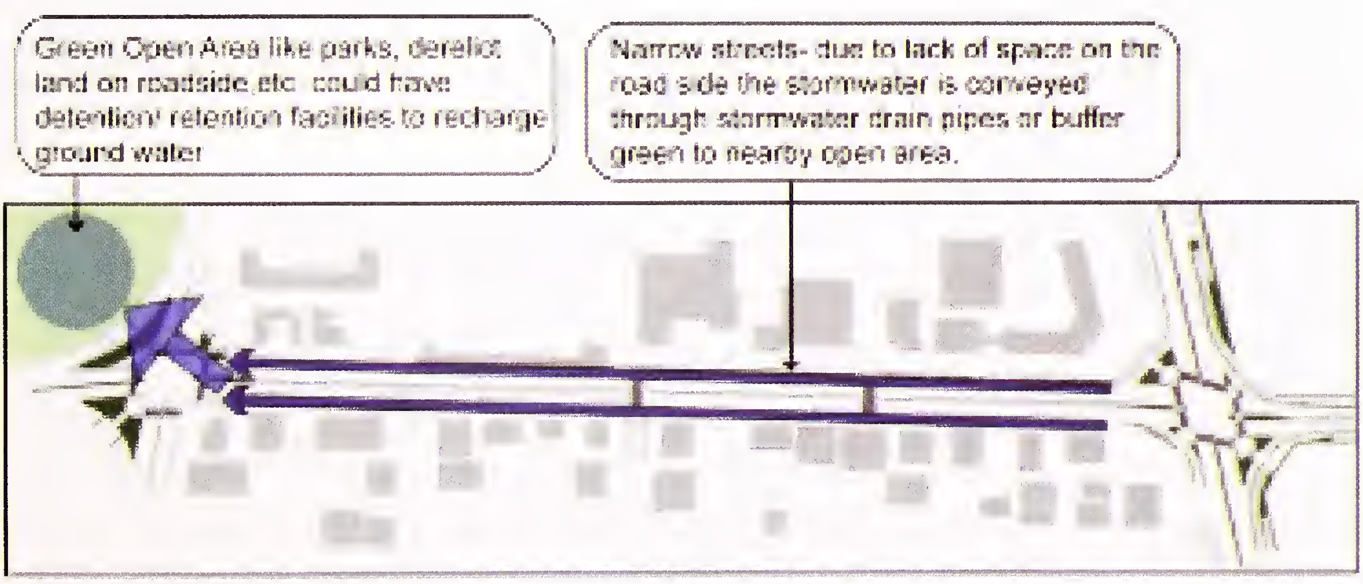


Fig. 10.1 (ii) (c)

Due to continuous addition of new colonies and urban extension areas, these drains could be designed calculating the actual discharge capacity. In such situations the most effective method of disposal of storm water would be by way of disposal into permeable strata of ground at all possible locations in drain itself or at vertical drains specially built for the purpose. An important aspect of drain is to ensure a good velocity in the drain not only when the drain is

flowing full but also when the drain is partially full. Usually, silt and other materials is deposited in the bed in large quantities and necessary silt traps shall be designed at frequent intervals for periodic removal of the same. The design need to be made to ensure self-cleaning velocity during dominant and lean flow conditions.

In most of the urban areas, the responsibility for design and construction of peripheral and trunk drainage system rests with Urban Local bodies. For an effective implementation of drainage system, proper co-ordination between all concerned agencies is compulsory between urban local bodies and PWD, Referred below {Ref **Fig. 10.1 (ii) (d) to 10.1 (ii) (n)**}.

1. **Storm water management strategy-**

For disposal of storm water along road side, the aim is to follow sustainable storm water management strategy.
The design strategy is to let the storm water falling on a particular catchment area, slows, spreads and soaks within that catchment area itself. As shown below:

Design Strategies for sustainable SWM

MANAGE STORM WATER *IN A CITY BY ADOPTING FOLLOWING MEASURES*

2. **Disconnecting the system-**

Another strategy for storm water management is to disconnect the conventional pipe system and using all possible alternate areas for ground water recharge.

Storm Water Management Strategy—disconnecting the system

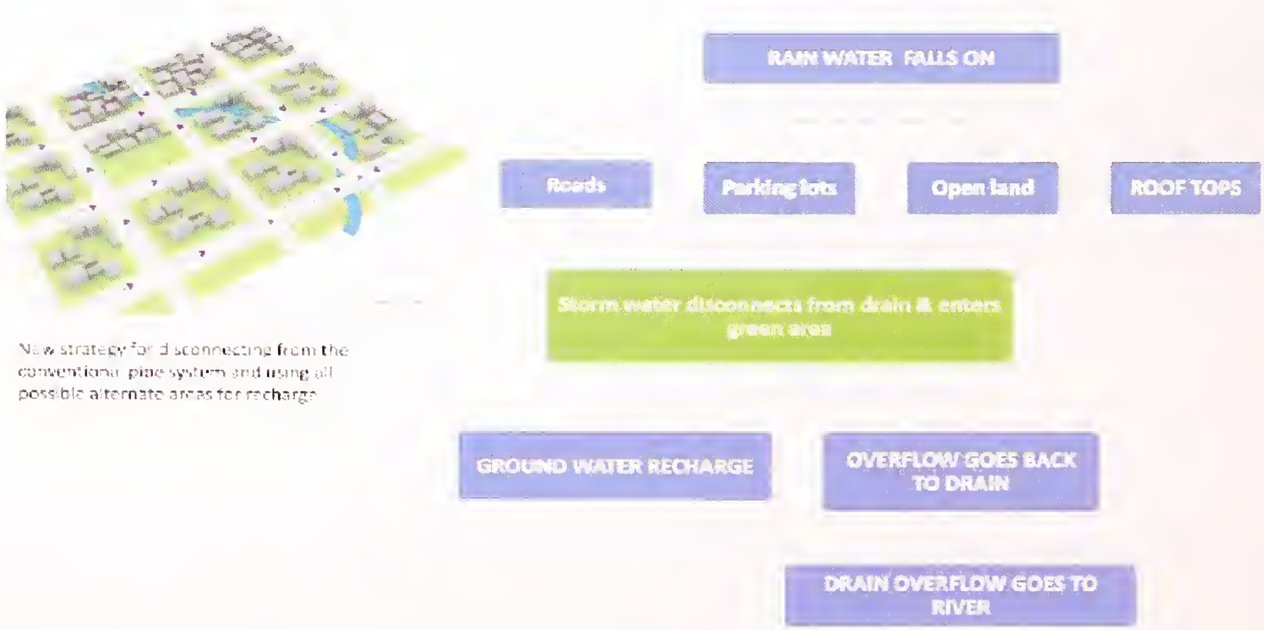
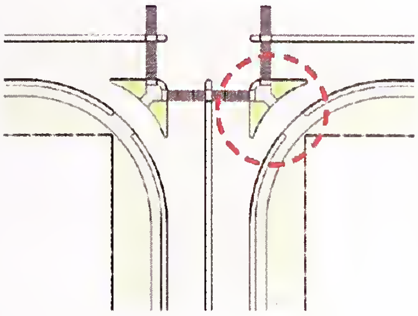


Fig. 10.1 (ii) (d) & 10.1 (ii) (e)

INFILTRATION

SWM in green islands on street



SWM in Triangular Islands

This shows the conventional way of slopes on road and storm water flow direction.

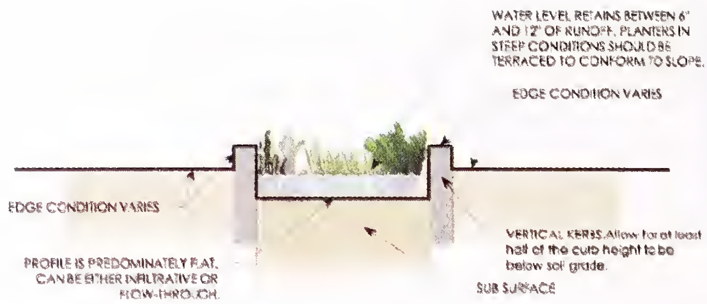
Fig. 10.1 (ii) (f)

CONVEYANCE

Planters

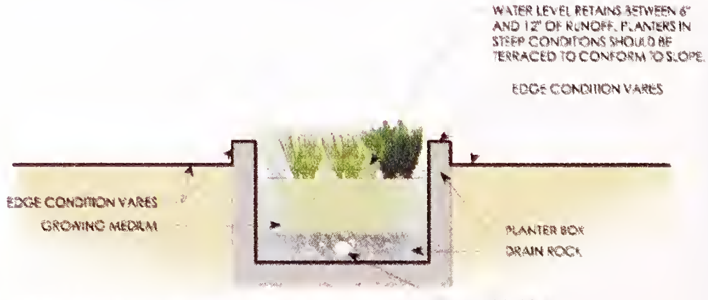
- Infiltration & Flow-through planters are structural landscaped reservoirs used to collect, filter, and infiltrate stormwater runoff.
- They allow pollutants to settle and filter out as the water percolates through the planter soil and infiltrates into the ground.
- Flow rates and volumes can also be managed with infiltration planters.

Planters are contained landscape areas designed to capture and retain storm water runoff.



At grade planter (Infiltration planter)

Filtration is required before the water goes through planter



Above grade planter (Flow through planter)

This type is possible where there is no sub surface, mostly over covered drains and basement slabs.

Fig. 10.1 (ii) (g)

1. *Street profile options*
2. *Managing steep topography*
3. *Designing with different soil conditions*
4. *Choose appropriate plant material*
5. *Soil preparation*
6. *Construction process*

Existing street with less area & barricade along pathway. Pedestrian walking on road

Proposed pathway with green buffer along trees

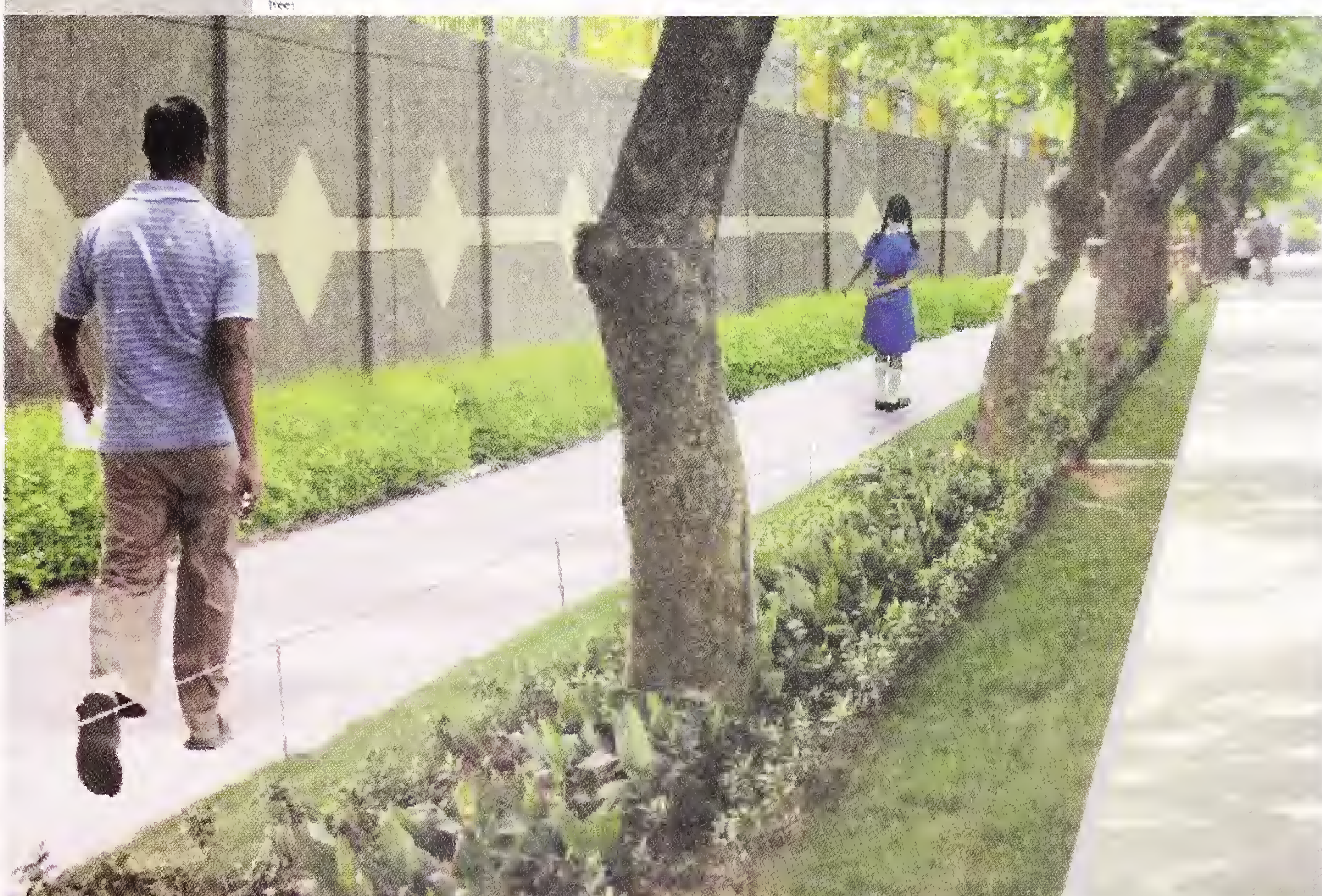
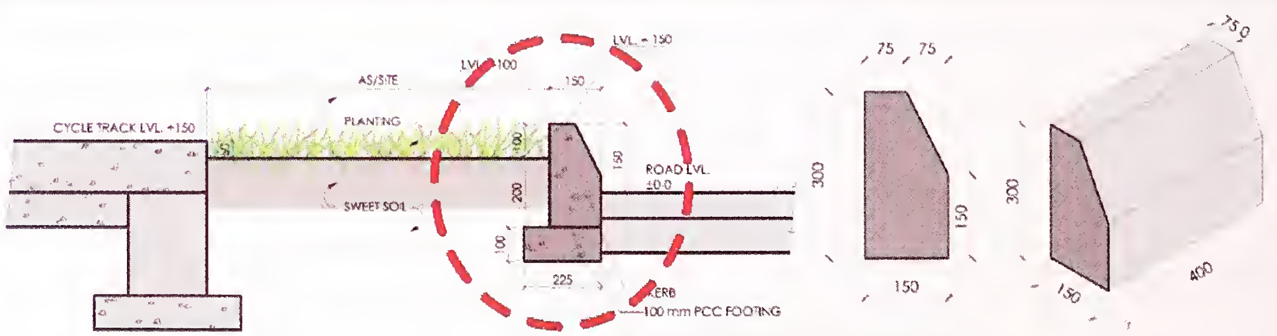


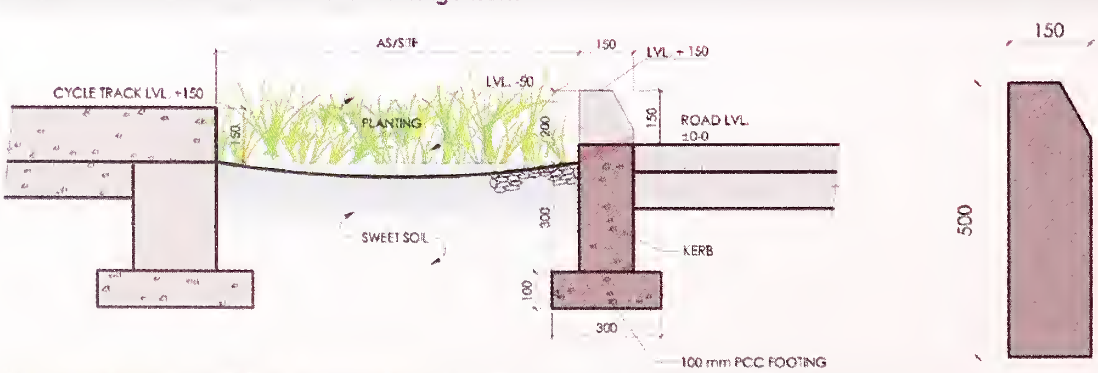
Fig 10.1 (ii) (h)

Conventional kerb stone used on road



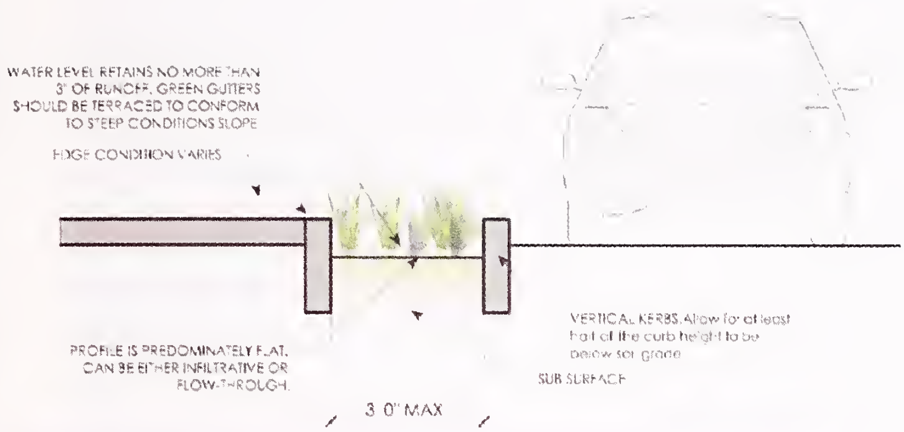
GREEN IS HIGHER THAN ROAD LVL

NEW kerb stone for Storm water management



DEEPER KERB STONE SHOULD BE USED TO ACHIVE LOWER GREEN AREAS.

Fig. 10.1 (ii) (i)



Green gutters help capture and slow storm water runoff within very narrow and shallow landscaped areas along a street's edge.

- They can often significantly "green" a street with minimal investment.
- Create a more walkable street environment by providing a green buffer between road traffic and the sidewalk.
- Require a long, continuous space to effectively slow and filter pollutants.
- These are very shallow and do not retain large amounts of runoff.

Fig 10.1 (ii) (j)

C O N V E Y A N C E

Green gutter

Green gutters are similar to Flow through planter with narrower width of the green area. Here the pollutant removal rate is less .

Fig. 10.1 (ii) (k)

CONVEYANCE

Planters

This green street features a continuous flow-through stormwater planter with multiple bridge pedestrian crossings

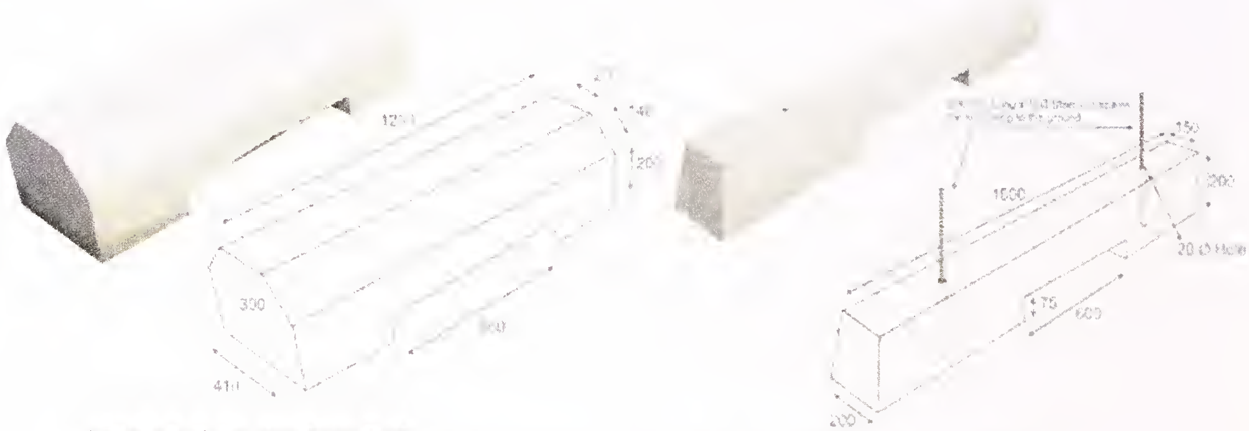
This arterial street was retrofitted with a series of stormwater infiltration planters.

A stormwater planter within the interior median of a parking lot.

Fig. 10.1 (ii) (I)

KERB STONE available in Existing Catalogues

Image source : ***KK manholes***



Advantages of using above kerb stone

1. Faster runoff of water from road to surrounding areas.
2. No water clogging on the roads & hence longer life of the road.
3. Rain water harvesting by the water is possible
4. Can be used as a sitting area along the footpath.
5. No separate drainage pipe required.

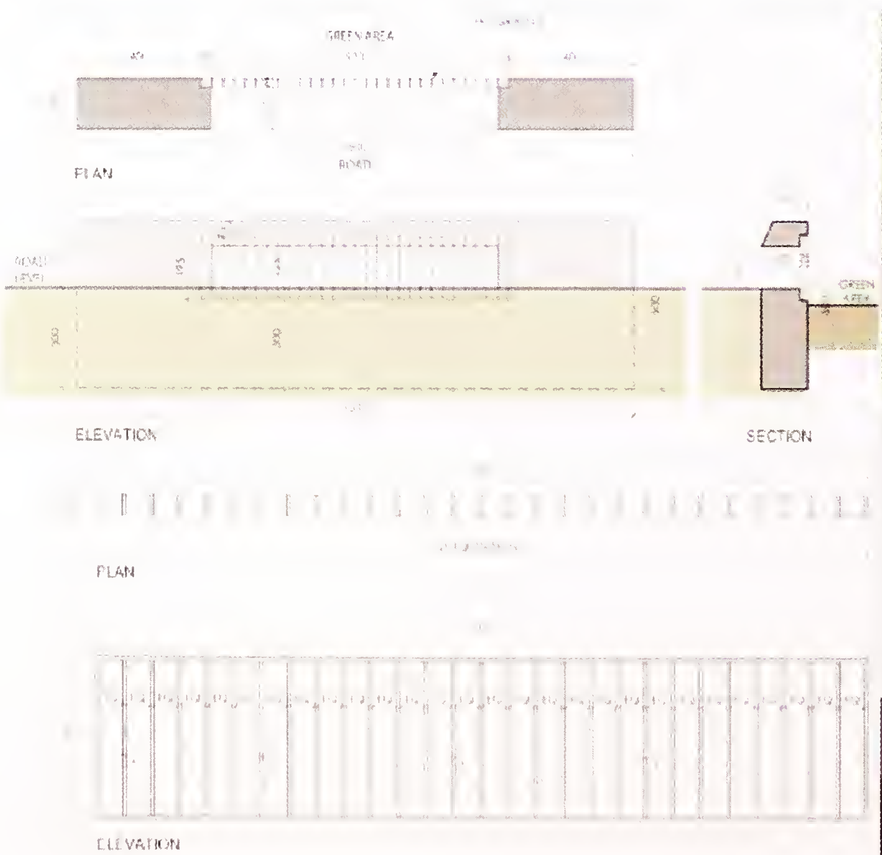
Konkrete Precast Concrete Products are manufactured using the latest vibro-compaction techniques, accurately designed moulds, appropriate reinforcement with circular plastic spacers and a concrete grade of M30 and above. We can also produce customised products for your special needs, subject to large quantities. To order customised products, sizes, strength required and other necessary information needs to be sent.
In our constant endeavour to improve the products, the specifications may change without notice.

All dimensions are in mm

BENEFITS OF PRECAST CONCRETE

STRENGTH – THE STRENGTH OF PRECAST CONCRETE GRADUALLY INCREASE OVER TIME. OTHER MATERIALS CAN DETERIORATE, EXPERIENCE CREEP AND STRESS RELAXATION, LOSE STRENGTH AND/OR DEFLECT OVER TIME. THE LOAD-CARRYING CAPACITY OF PRECAST CONCRETE IS DERIVED FROM ITS OWN STRUCTURAL QUALITIES AND DOES NOT RELY ON THE STRENGTH OR QUALITY OF THE SURROUNDING BACKFILL MATERIALS.

KERB STONE with FRP Grating



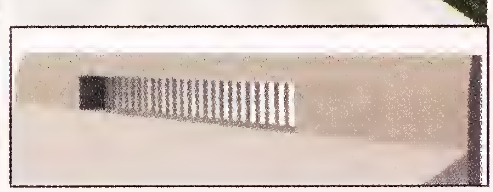


Fig. 10.1 (ii) (m)

This is a large triangular island at junction, where the road is on a steep slope. A series of storm water planter provided in the area to collect water at different levels. Excess water goes to the next planter below and then finally to nearby drain

DESIGN & CONSTRUCTION DETAILS

Design with different soil conditions

In every city, many sites will not always have both flat terrain and high percolation rates required for infiltration facilities.

- Infiltration facilities should not be designed to retain storm water in areas, that have a high water table, or with some soil contamination.
- Infiltration is also infeasible in areas with steep slopes or high clay content soils.

Therefore, we have to follow different techniques other than storm water infiltration.

- Calculate the infiltration rate of particular site.
- Reduce impervious area, that will reduce the amount of runoff needing treatment. (as increasing a site's landscape area by 25% will result in decreasing the site's storm water runoff by almost 25% even without the use of active storm water facilities.)
- Additional under drain (perforated) will be required for soils with low infiltration rates, so that excess water can get its way to storm drain system.

Some sites , where there is poor soil and less space, parking can be provided on the same with pervious paving

Fig. 10.1 (ii) (n)

These can be adopted in roads where right of way is wide and can be incorporated in planning new extensions in addition we can provide French drains either to break monotony or area available does not permit landscaping. See Photos above.

French Drains

This is the most popular type of drainage system used in rural dual carriageway and motorways in Ireland and other Countries. It consists of either a porous, perforated or open-jointed non-porous pipe at the bottom of a trench filled with gravel laid at the edge of the pavement or close to it. It serves both purposes of surface and subsurface drainage and is called a combined filter drain. It is mainly used in cutting or areas with ground water problems. It also provides storage of runoff during storms that may help to attenuate flood peaks at the receiving stream due to the time lag.

The earliest forms of French drains were simple ditches, pitched from an area to a lower one and filled with gravel. These were described and popularized by Henry Flagg French (1813-1885) a layer and assistant treasury secretary from concord, Massachusetts in his book farm drainage. French's own drains were made of sections of ordinary roofing tile laid with a 1/8 in (0.32 cm) gap left in between the sections to admit water. Later, specialized drain tiles were designed with perforations. To prevent clogging, the gravel size varied from coarse at the center to fine at the outside and was designed based on the graduation of the soil surrounding the drain. The practical sizing was critical to keep the surrounding soil from washing into the voids in the gravel and clogging the drain. The development of geo textiles greatly simplified this procedure. See **Fig. 10.1 (ii) (p)**

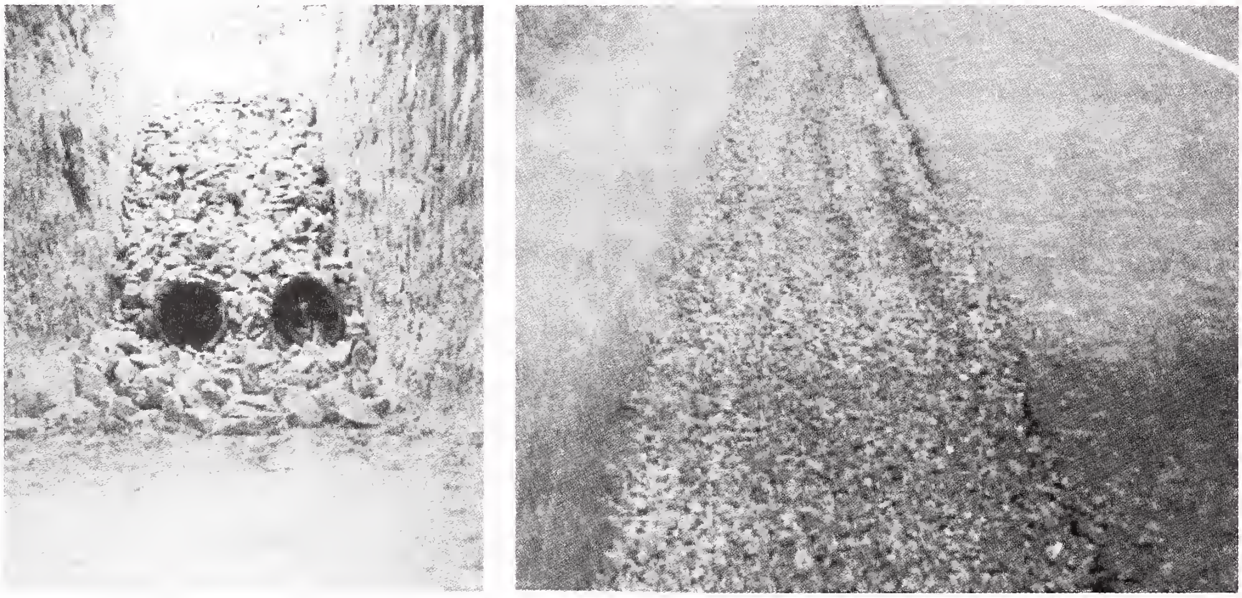


Fig. 10.1 (ii) (p) French Drains

10.1.iii. 1 *Providing bore wells in tertiary & secondary drains*

Deep bore wells can be provided in tertiary and secondary drains more so in valley points for infiltration of water into the ground.

10.1.iii. 2 *Disposal of storm water for ground water recharging on new roads*

The most effective ground water recharging can be carried out while construction of new roads. This system shall be part and parcel during formation of new layouts.

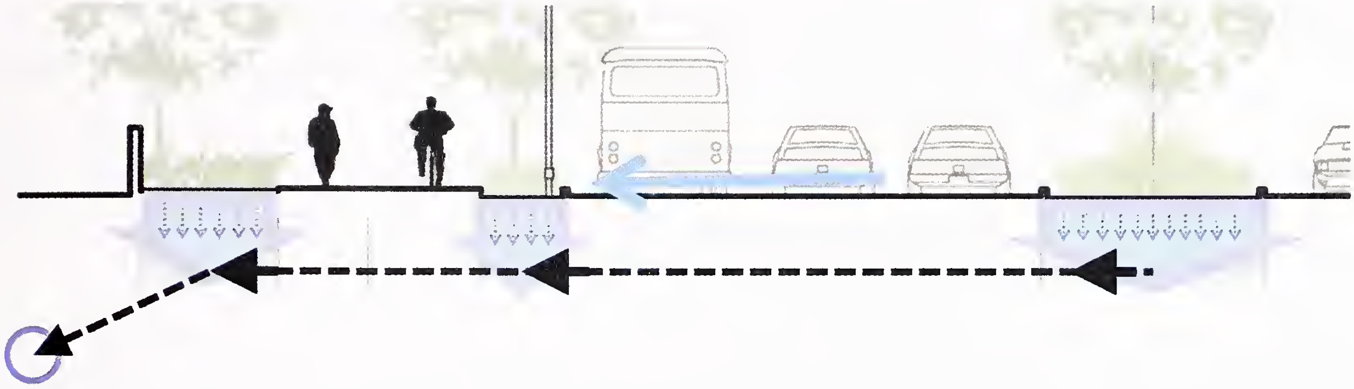


Fig. 10.1 (iii) (a) Cross Section of Typical Road Side Detail Showing a Retro Fit Option for Storm Water Management Facilities

- Median only collects the rain water falling on its own surface area, as the road camber is towards the road side greens.
- Run off from entire road enters the road side greens.
- Over flow from the green areas should always go to nearby open land / parks or existing pipe system after passing through the infiltration layers depending on the type of storm water facilities implemented depending on the size.

While building new roads, the storm water facility on a road should be mandatory. The type of storm water facility to be used depends on the street profile or typology. For new construction, there is far more flexibility for storm water management because the street profile can be designed in a variety of ways.

	Permeable paving	Vegetated and Gravel Filter	Flow through and Infiltration Planter	Swales	Rain Gardens	Green gutters
6m wide Road	O					O
9m wide Road	O		O			O
12m wide Road	O	O	O	O		O
18m wide Road	O	O	O	O	O	O
				Only if there is a kerb extension		
24m wide Road	O	O	O	O	O	O
30m wide Road	O	O	O	O	O	O
40m wide Road	O	O	O	O	O	O
45m wide Road	O	O	O	O	O	O
60m wide Road	O	O	O	O	O	O

Fig. 10.1 (iii) (b) Storm Water Management on Street Types

10.1.iii.3 Providing Landscaping in Round Abouts medians, traffic channels, sidewalks (where the width is more than prescribed in IRC) and adoption of French drains & adoption of French drains

City roads are designed with round about's at junctions, channels, islands, sidewalks. These can be landscaped with shrubs and tottering plants, grass and the road surface storm water can be led to these landscaped areas with open kerbs.

Rotaries normally cater for low traffic volume intersections and for super elevation requirement, water from a large area flows towards center of the rotary. This water could be in filtered into the ground for ground water recharge by directing the entire road slope towards the green areas like in the roundabout or traffic islands which can act as rain gardens as shown in **Fig. 10.1 (iii) 3.(a) to 3. (d)**.

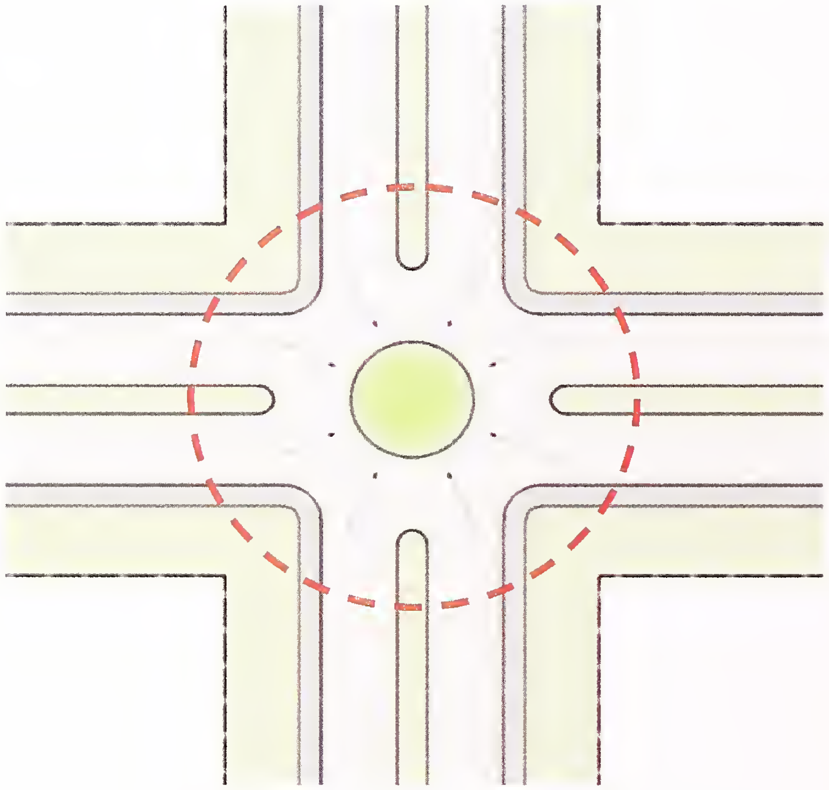


Fig. 10.1 (iii) 3 (a) Rain Gardens in Round About

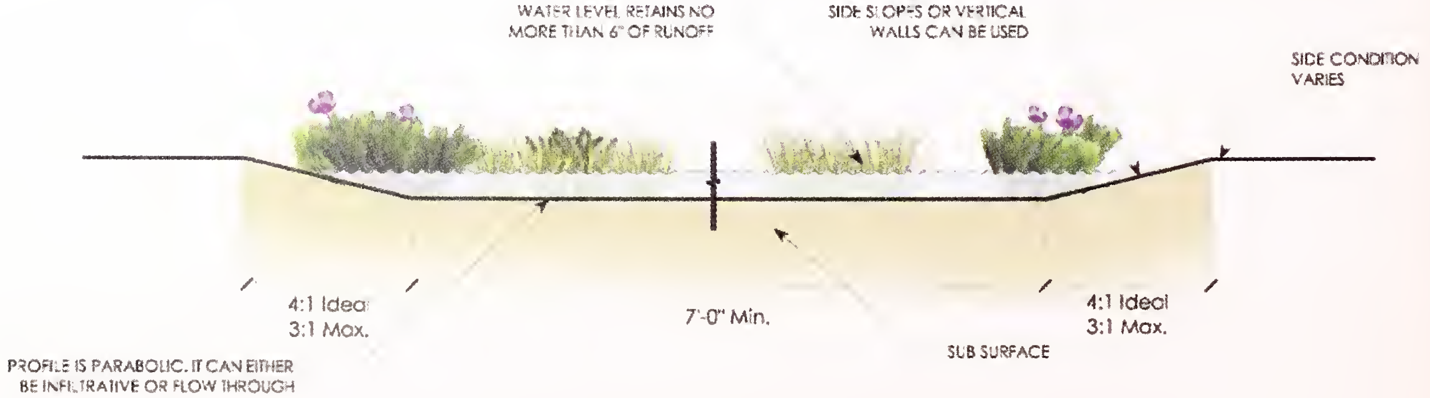


Fig.10.1 (iii) 3 (b) Rain Garden Schematic Cross-Section

- Rain gardens are shallow landscape areas that can collect, slow, filter and absorb large volumes of water, delaying discharge into the watershed system.
- Rain gardens retain storm water, thereby reducing flow rate and overall volume.
- They can also allow for infiltration, depending on the capacity of the native soil.

At intersections the green island can act as rain gardens to take in all the storm water from adjacent areas and then the over flow could be drained out by main drainage pipe. By providing kerb cuts in the street kerb, storm water flow can be managed, as shown in the **Fig. 9.7 (a)** in Chapter-9.

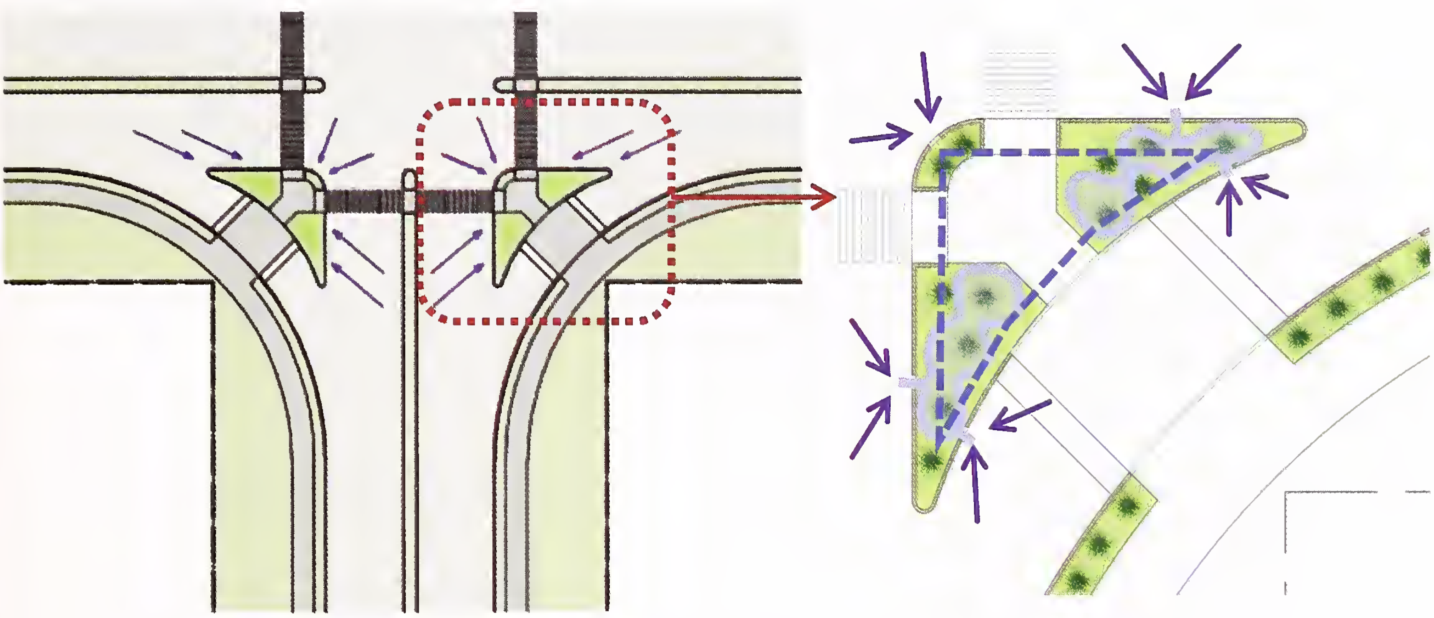


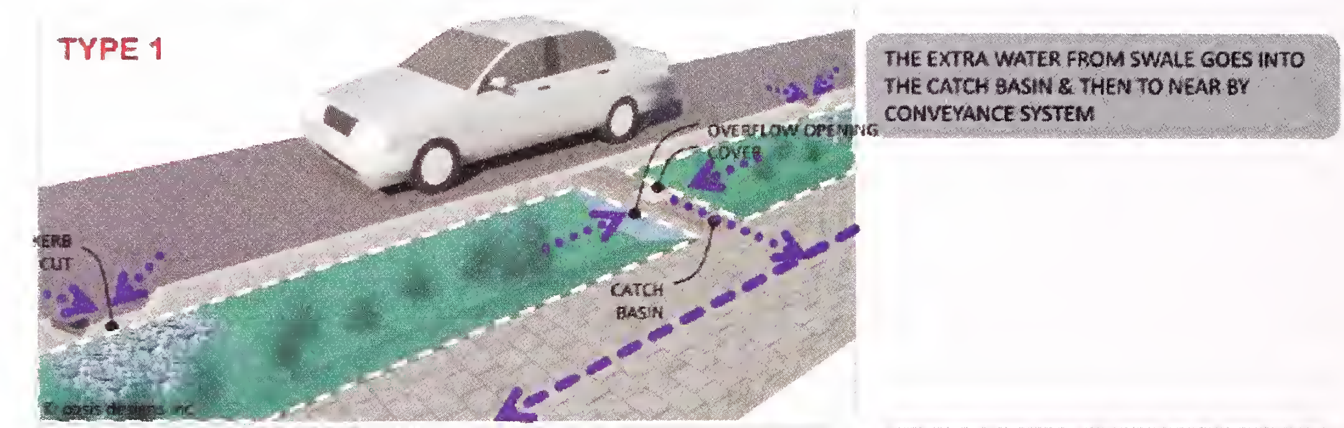
Fig. 10.1 (iii) 3 (c) Rain Garden in the Traffic Island

Image also shows schematic direction of slope.

OVERFLOW CONDITION

Overflow options are must for any and every storm water management systems to avoid extreme situations. Overflow within these areas can be managed in many ways depending on type of storm water infrastructure is already available.

OVER FLOW OPTIONS



OVER FLOW OPTIONS – TYPE 3

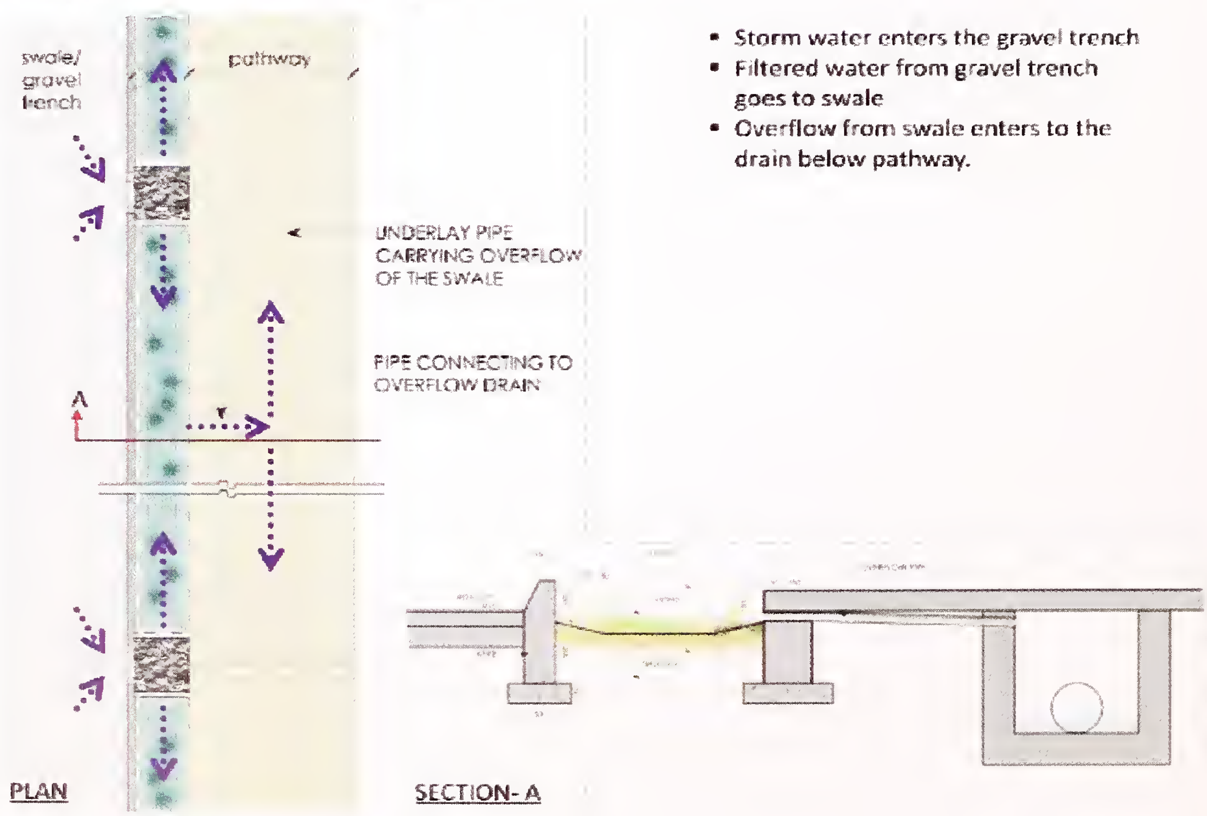
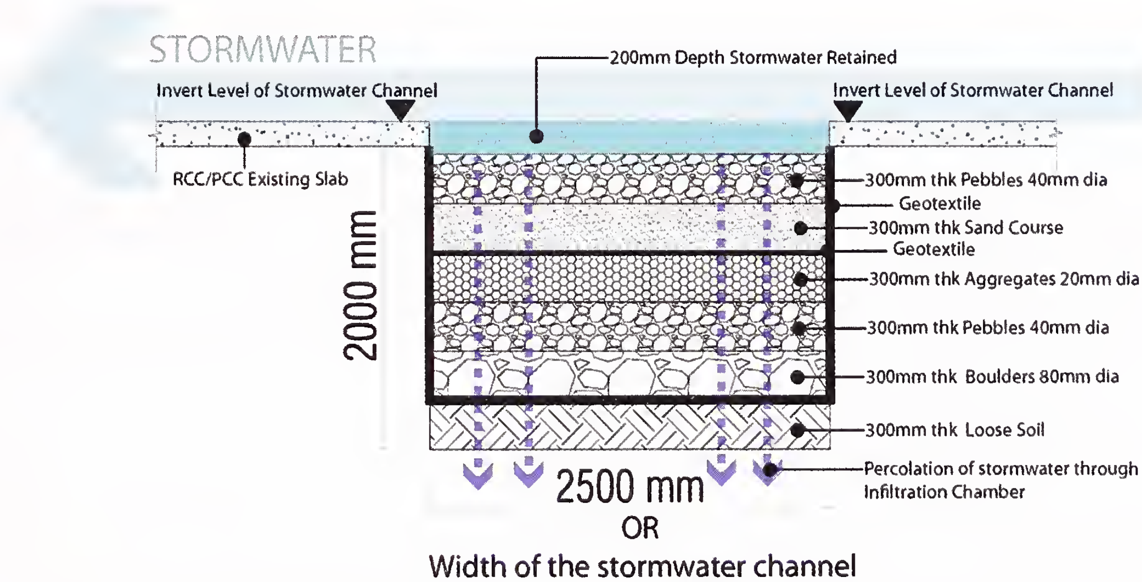


Fig 10.1 (iii) 3 (d) Types of Over Flow

10.1. iv *Use of secondary drains of pours layers & filters materials*

In order to effectively infiltrate storm water into the sub-soil, the longitudinal gradient of the drain shall be effectively utilized by creating flow stoppers at regular intervals, so that maximum depth of stagnation can be 300 mm in road side, tertiary drains, and it shall be 400 mm in secondary and primary drains. Before erecting flow stoppers, the required length of bottom portion of drain shall be exposed for infiltration with suitable modification by providing filter medium, which shall primarily be of fine-course aggregate combination with a layer of perforated polyester fabric like geo textile, geogrid or netlon. **Photo 10.1. iv (a) to Photo 10.1. iv (f)** shows various stages of conversion of existing drain without flow stoppers for ground water charging.

Photo describe the infiltration mechanism.



CROSS SECTION OF INFILTRATION CHAMBER

Photo 10.1. iv (a) Infiltration Gallery for Ground Water

Photo 10.1. iv (b)

Photo 10.1. iv (c)

Photo 10.1. iv (d)

Photo 10.1. iv (e)

Photo 10.1. iv (f)

Various stage of converting existing drain for ground water recharge

All types of infiltration facilities shall have pervious bottom for effective ground water charging in order to drain the basin. Detailed engineering geological studies are necessary to ensure that infiltration facility can function as planned. Particulates for in flow shall be removed, so that they do not settle and preclude infiltration.

Another option for handling overflow is to construct a new storm drain/overflow channel inlet within the storm water facility as shown below:

10.1.v *Detention and retention ponds*

Detention System :

Detention systems are designed to store storm water temporarily and then release or reuse it gradually.

- The primary purpose of detention basins is to control storm water runoff. Detention systems store runoff for up to 48 hours after a storm and are dry until the next rain fall. This provides pollutant removal by temporarily capturing runoff.
- This helps in preventing flooding of low lying areas and storm water drains during heavy rains resulting in loss of life and property.
- Detention storage can be provided at one or more locations and can be above ground or below ground. These locations can exist as impoundments, collection and conveyance facilities, underground tanks and on site facilities such as parking lots, basins etc. The facility may have a permanent pool, known as wet pond. These ponds can be typically used where pollutant control is important. Detention ponds can be common type of storage facility used for controlling storm water runoff peak discharges. The majority of

these are dry ponds which release all the runoff temporarily detained during a storm. They can also be located in large open areas of central/defense/ Government lands and private properties.

Different Types of detention systems:

a) **Detention pond :**

- Detention ponds are temporary holding areas for storm water that store peak flows and slowly release them, reducing the demand on treatment facilities during storm events and preventing flooding.
- Detention ponds are designed to fill and empty within 48 hours of a rain fall and could reduce peak flows and runoff volumes.
- They can be used to provide flood control by including additional flood detention storage.

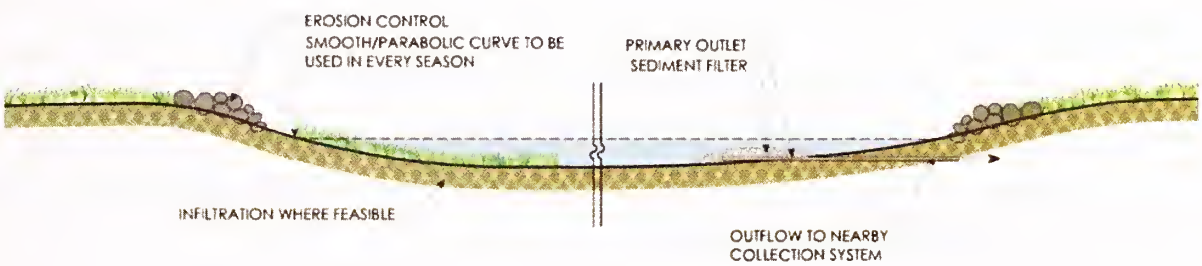


Fig. 10.1.v (a)

b. **Dry Swale :**

- Dry swales are simple drainage and grassed channels that primarily served to transport storm water runoff away from roadways and rights-of-way.
- This provides both quantity (volume) and quality control by facilitating storm water detention.
- Dry swales are used at low density residential projects or for very small impervious areas.

Retention Systems :

- Retention facilities are basically extended detention facilities, infiltration basins and swales. In addition to storm water storage, retention facilities may be used for water supply, recreation, pollutant removal, aesthetics and importantly recharging of ground water. In the context of serious depletion of ground water table, these infiltration facilities provide significant water quality benefits and although ground water recharge is not a primary aspect of urban storm water management, the infiltration basins need to be used for the primary benefit of urban area.

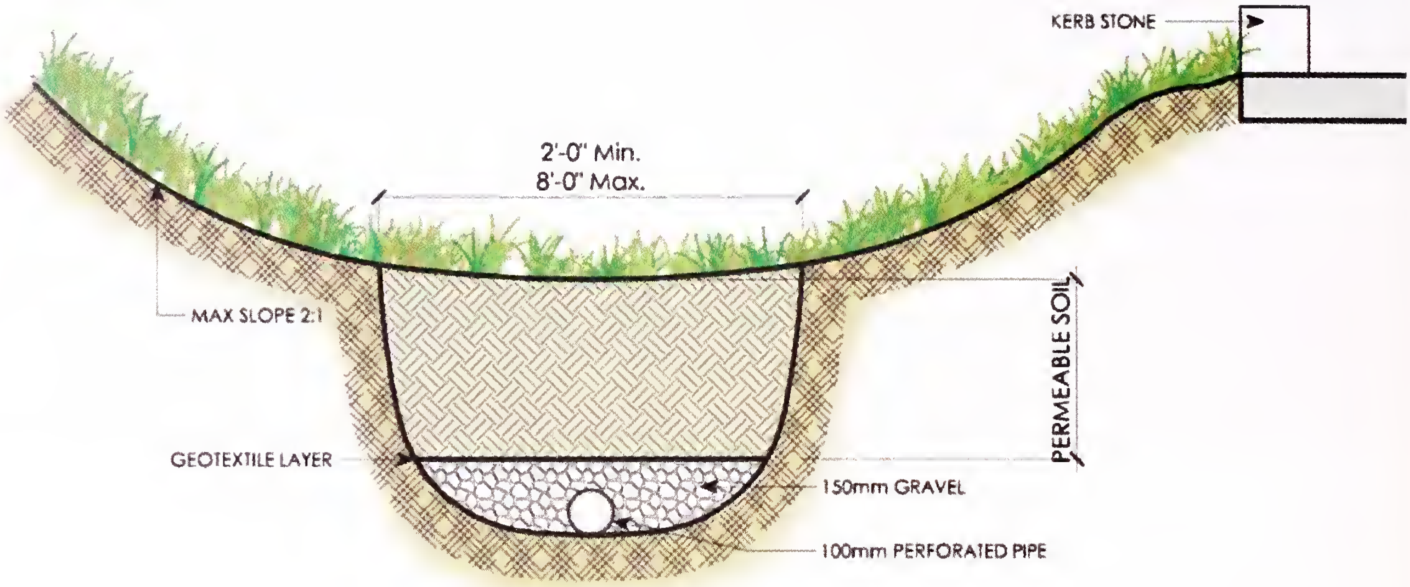


Fig. 10.1.v (b)

- Retention facilities shall be designed to provide both functions of storm water quantity and quality control. These facilities can be provided at one or more locations and may be above or below ground in large open areas vested with central/state/urban bodies.

Types of retention systems are

a) **Retention pond :**

- Retention ponds maintain a permanent pool of water in addition to temporarily detaining storm water. These ponds fill with storm water and release most of it over a period of a few days, slowly returning to its normal depth of water.
- As these have to maintain a permanent pool, they can't be constructed in areas with insufficient precipitation or highly permeable soils.
- Retention ponds can have aquatic habitat if properly planted and maintained. Regular cleaning and maintenance is needed to ensure proper drainage.
- Areas of possible application: Unused open areas, maidens, Open spaces in the city parks.

b) **Constructed wetland :**

- Constructed wetlands are shallow, man-made pool with vegetated systems designed to provide storm water retention and pollutant removal.

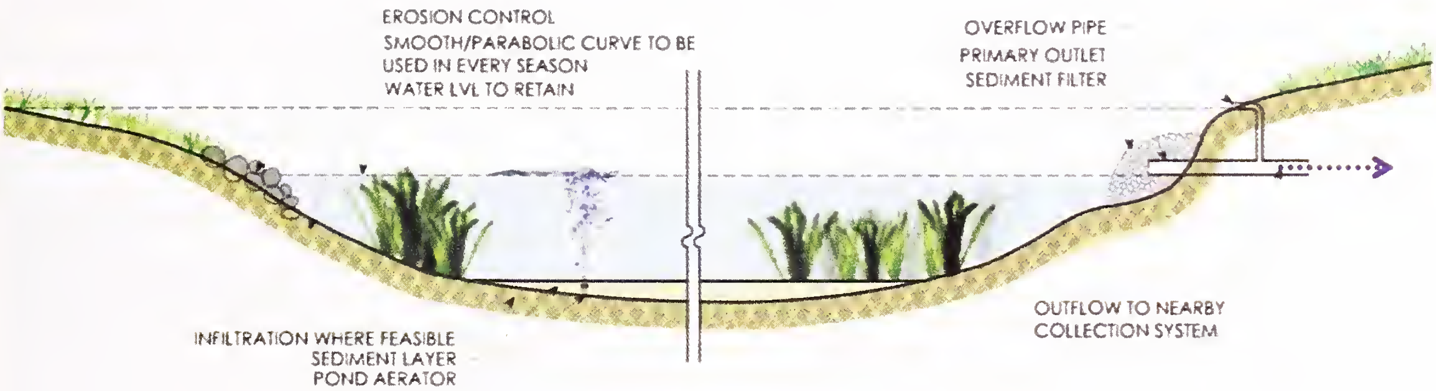


Fig. 10.1. v (c)

- Can be designed for enhanced nitrogen removal by creating aerobic and anaerobic zones
- Reduces runoff temperature
- Creates habitat. Plants and wetland helps to reduce storm water speed and allows sediment to settle out.
- These can be applied to the areas those were wetland once or low line areas of any site.
- These are different from retention ponds in their shallower depths and large vegetation coverage.

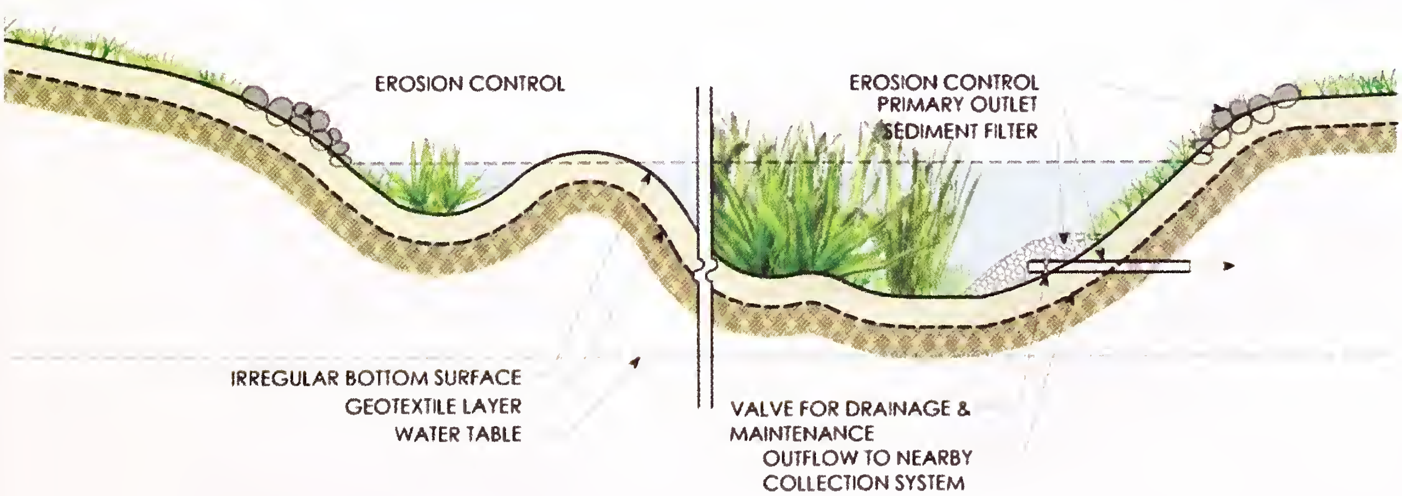


Fig. 10.1. v (d)

These Types have been sketched and shown in **Fig. 10.1. v (a) to 10.1 v (d)**.

10.1.vi *Use of porous layers*

Some of the developed countries are adopting pervious paving for side walks and also carriage way this allows water to infiltrate below the paving and then in to soil and ground

water below. By infiltrating most of the storm water on site, the amount of water flowing into storm water channels is considerably reduced. See **Fig. 10.1.vi (a) and (b)**.

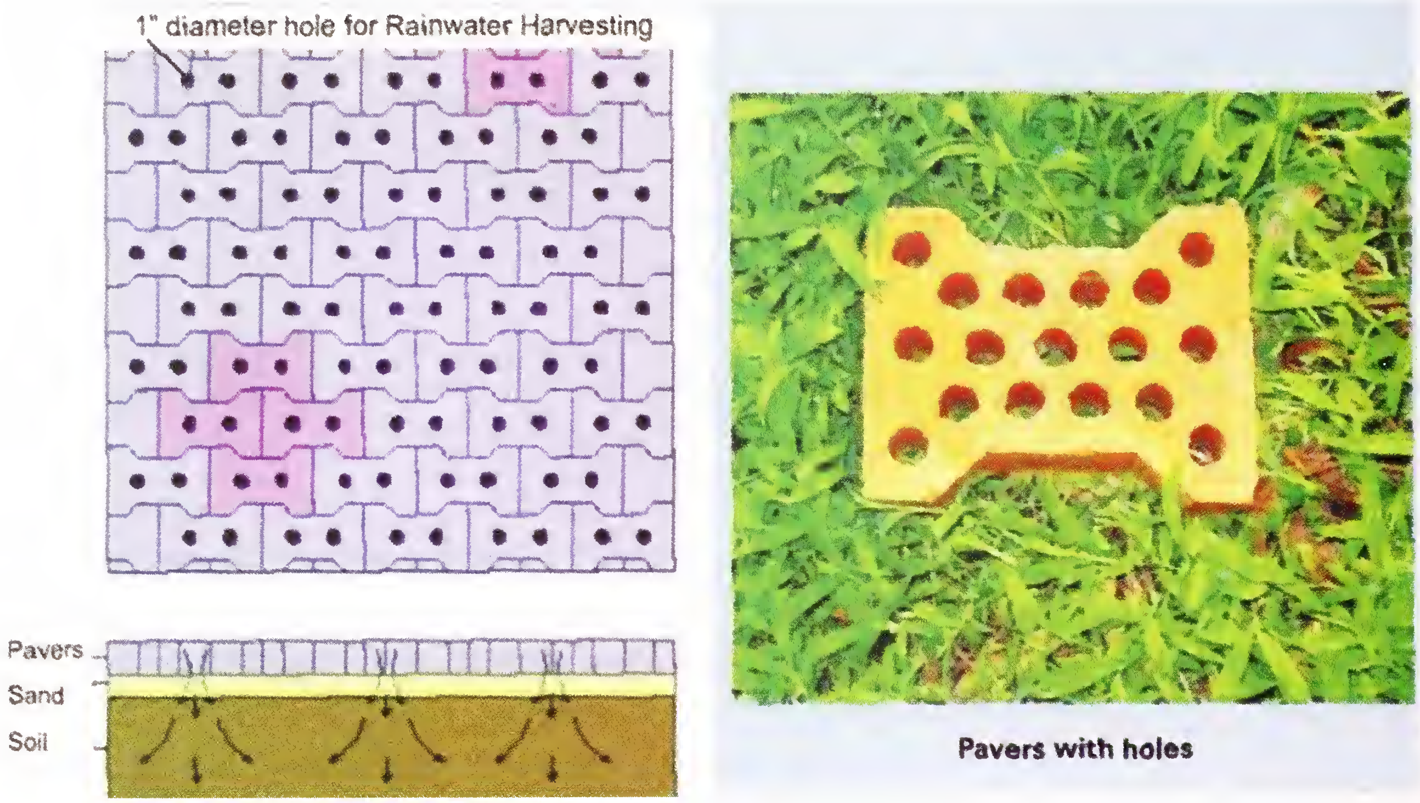


Fig. 10.1.vi (a)

TYPE OF PERVIOUS PAVING

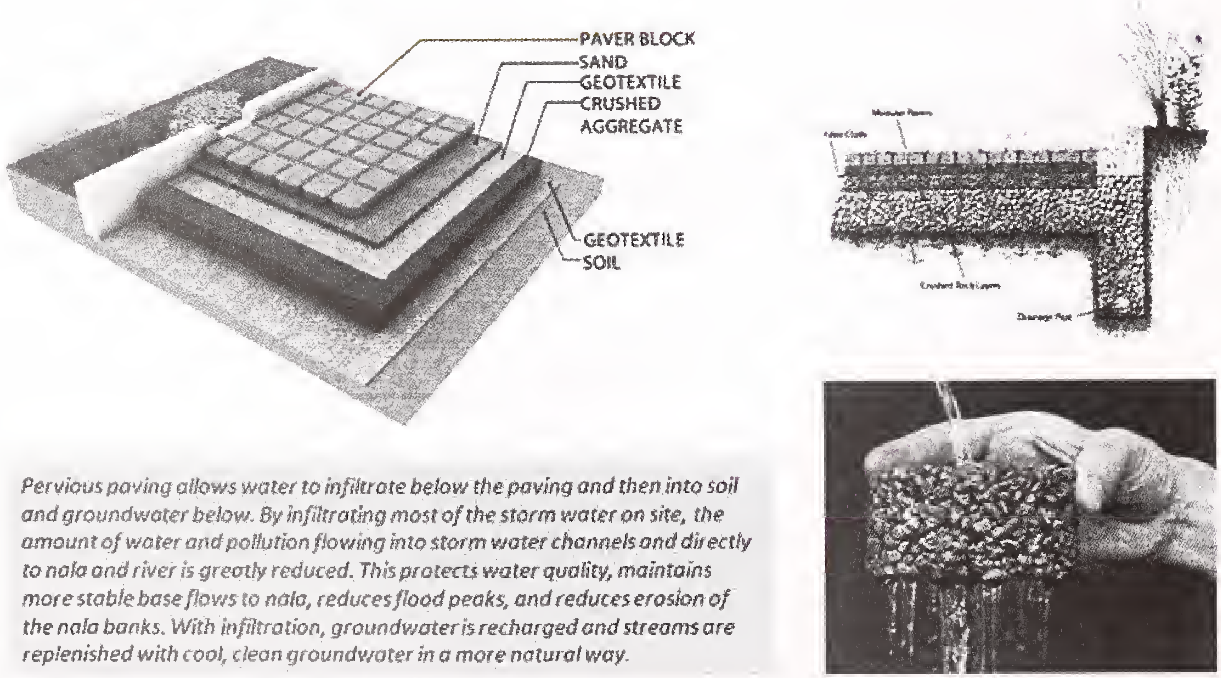


Fig. 10.1.vi (b)

10.1.vii *Perforated paving and landscaping in parking lots*

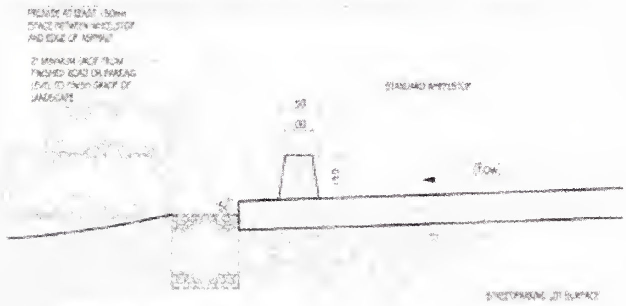
The runoff during rains can be recharged into the ground by landscaping and use of perforated paver blocks in landscaping in parking lots. See **Fig. 10.1.vii (a) and (b)**.

10.1. viii *Rain water harvesting in buildings*

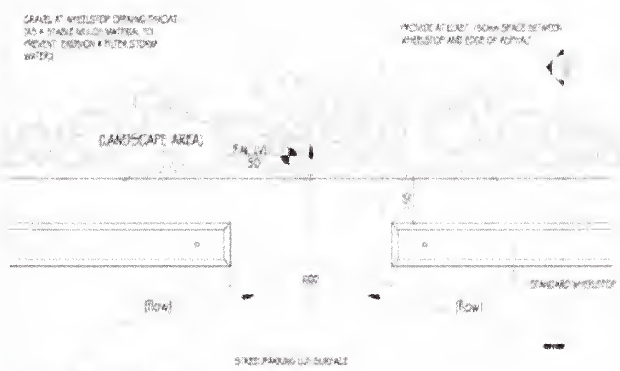
Rain water harvesting is the process of collecting and storing rain water for future use. Rainwater harvesting in large areas with open ponds, lakes, tanks and roof top, it is estimated that in a roof area of 100 sqm with annual rainfall of 1000 mm the roof yield is 1 lakh liter per year which is allowed to go waste and also can cause flooding of storm drains in urban areas with lakhs of square meters of built up area. See Figures and Photos showing the arrangement and collecting of rain water.

Many of the urban local bodies have made it mandatory to provide rain water harvesting in respect of residential sites of more than 200 sqm and also water supply organizations (Govt. Undertakings) have made rain water harvesting compulsory in order to provide water supply and UGD connection. Extended concession is extended in the water charges by water supply agencies.

Kerb type to use in parking lot

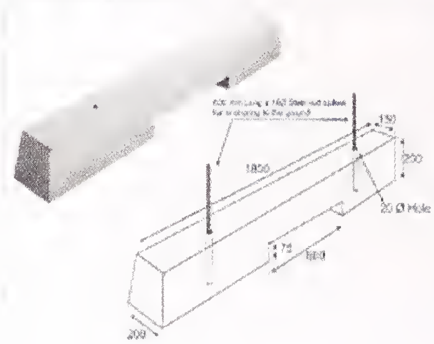


1 KERB CUT SECTION
SCALE - 1:10

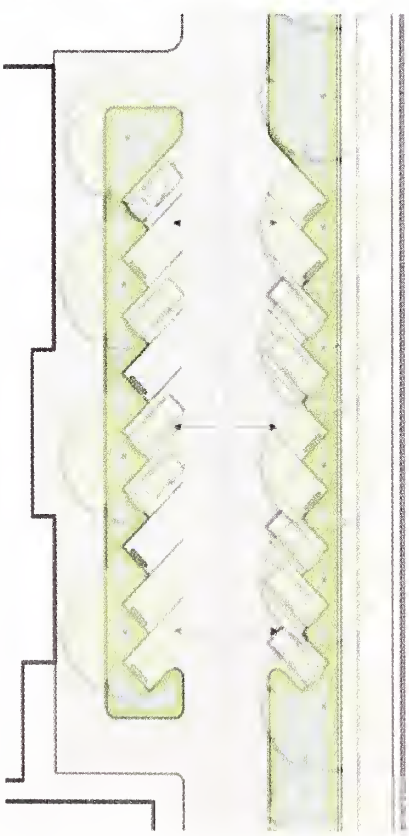


2 KERB CUT PLAN
SCALE - 1:10

WATER FLOWS TO STORM WATER CHANNELS THROUGH WHEEL STOP



Angled parking lot



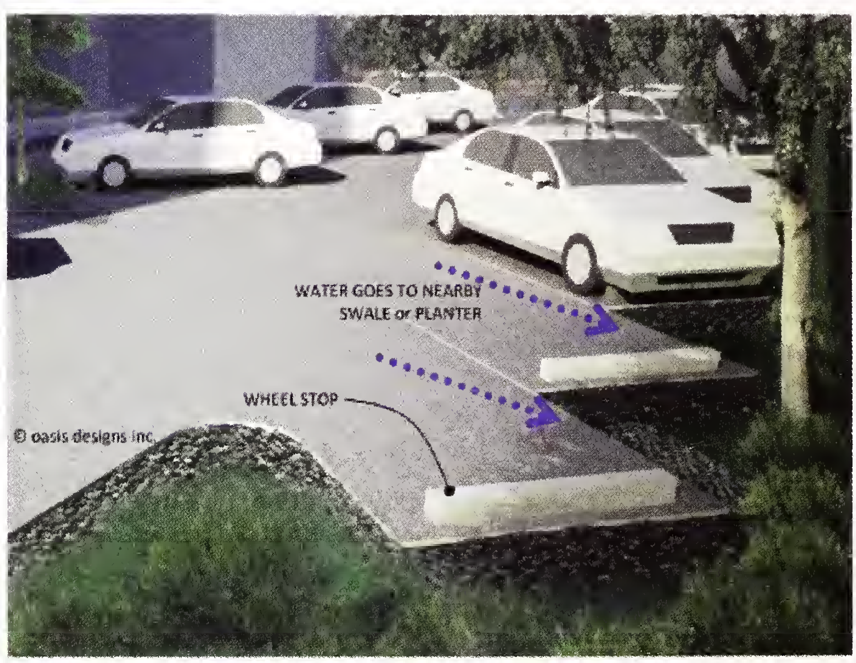


Fig. 10.1.vii (a)

Parking lot with pervious paving

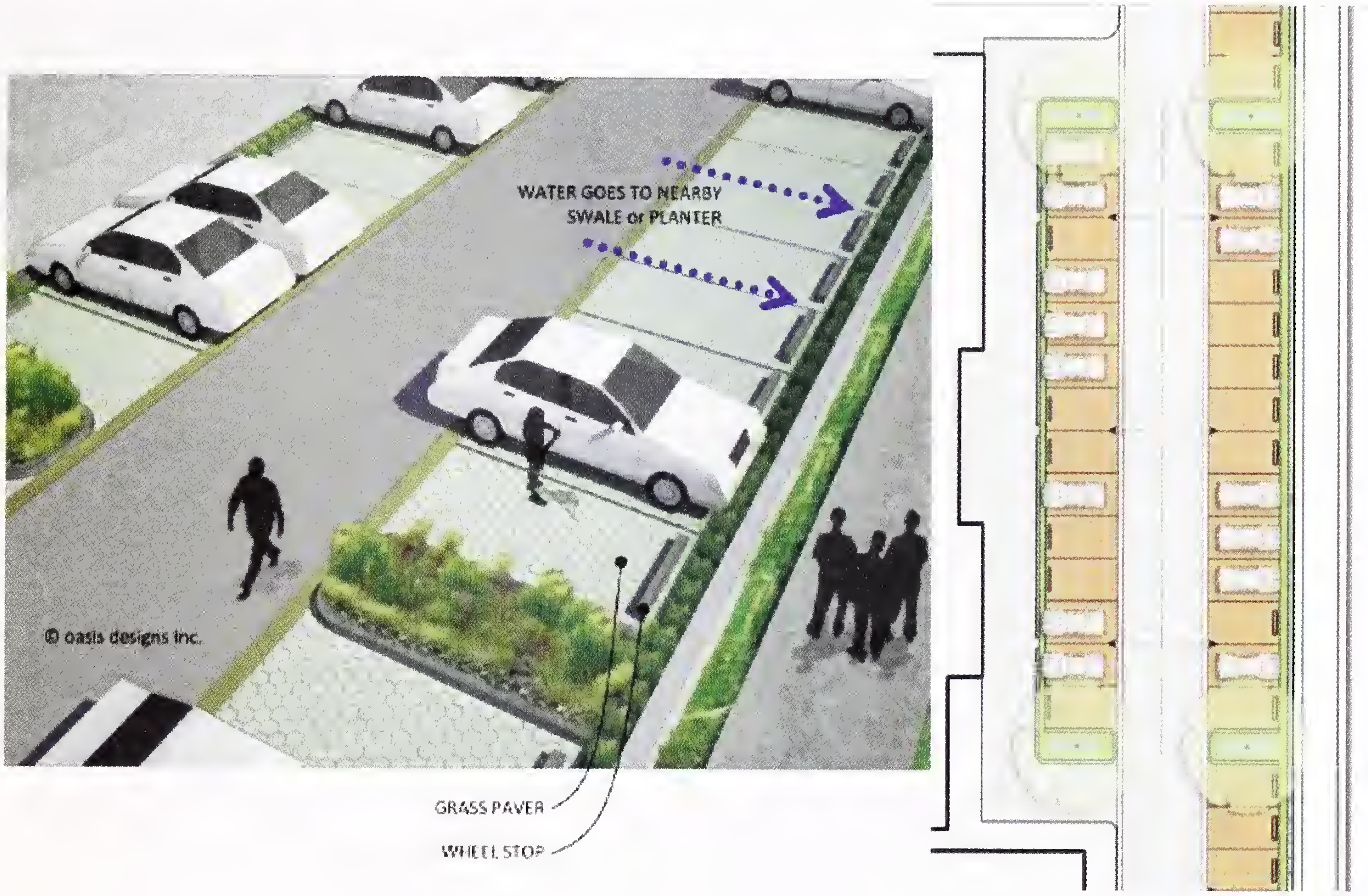


Fig. 10.1.vii (b)

Average annual rain fall data of one hundred years of metropolitan cities in the Country is given below:*

i)	New Delhi	718 mm
ii)	Kolkata	1670 mm
iii)	Mumbai	1971 mm
iv)	Chennai	1333 mm
v)	Hyderabad	787 mm
vi)	Bangalore	929 mm

* Karnataka State Council for Science and Technology
Indian Institute of Science, Bangalore

Advantages of Rain Water Harvesting

i) Storm water can be collected and reused for non-potable water uses within a house or building, or for landscape irrigation purposes.

ii) Uses can include reusing water in toilets.

iii) This will help to reduce the water used from the City water system.

iv) Rainwater harvesting can be used to manage a portion of the storm water flow and lessen the overall flow control requirement. Refer **Fig. 10.1. viii (a) and (b)**

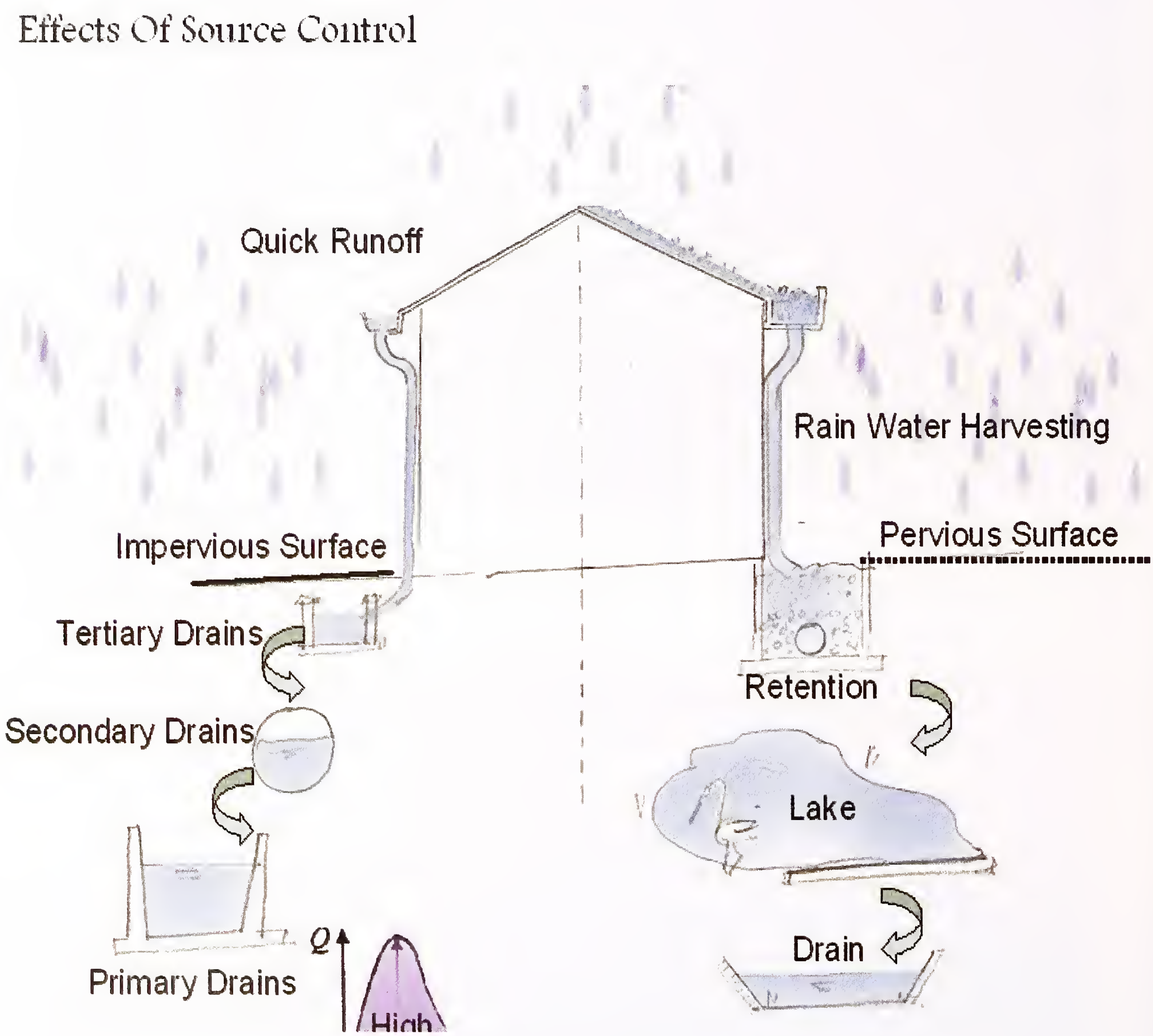


Fig.10.1. viii (a)

Fig. 10.1. viii (b)

11 DRAINAGE THROUGH PUMPING

11.1 Wherever storm water cannot flow into drainage system by gravity, especially in low lying areas below bed level of adjoining storm water drain, pumping is the best solution. Sump tanks with storm water pumping stations will be necessary for removal of storm water from road sections, in respect of structures like under passes, road under bridges, a few types of flyovers, where road is required to be depressed to get minimum vertical clearance. The storm water accumulated on the pavement is channelized to a sump tank and then pumped to the nearest drain; from therein it flows by gravity. In recent development, the sump tanks are also used as infiltration tanks by providing open bottoms with necessary filtration system, which will reduce load on pumping stations. Adequate capacity of sump, pump and reliability of the pumping system and continuous power are essential, in order to avoid disruption of traffic in such locations. Pumping is also required at the tail end of a drainage system to discharge the out flow above HFL or any such designated level.

11.2 Design of pumping stations depends on quantity of storm water to be pumped out, type of equipment used, the pumping station's and availability of land. Pumping station shall be located and that it would not be flooded at any time. The intake structure shall be constructed in such a way that it will supply even distribution of flow to the pumps. An uneven distribution may cause strong local currents resulting in reduced pump efficiency and undesirable operational characteristics. The ideal approach will be a straight channel coming directly into the pump or suction pipe. Turnings and obstructions are detrimental, as they may cause eddy currents and tend to initiate deep cored vertices. The inflow shall be perpendicular to a line of pumps and water should not be allowed to flow past one pump to reach another. The discharge piping shall be kept as simple as possible. The pumping systems that lift the storm water vertically and discharges it through individual lines to a gravity storm water drain as quickly as possible are preferred. Trash racks shall be provided at the entrance to the wet well if debris is anticipated. If substantial amounts of sediments are anticipated, a chamber may be provided to catch solids that are expected to settle out. This will minimize wear on the pumps and limit deposits in the wet well. The grit chamber shall be designed so that a convenient means of sediment removal is available. See **Fig.11.1**.

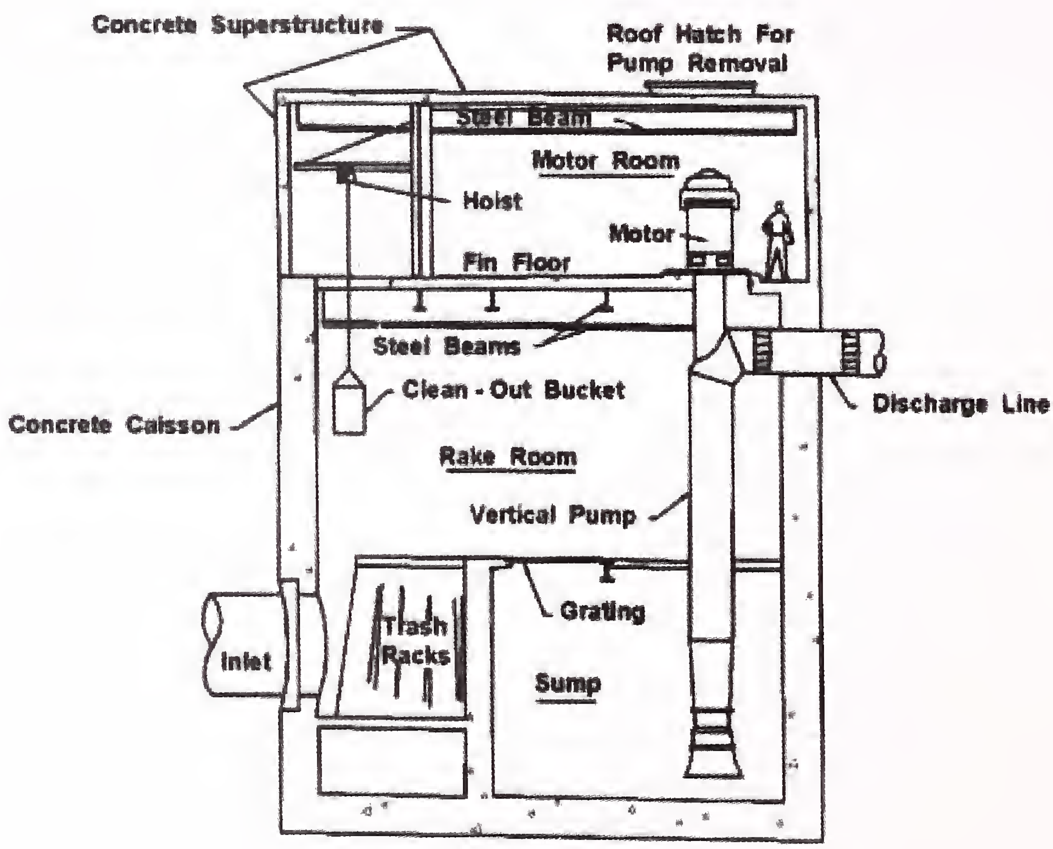


Fig. 11.1 Typical Wet-Pit Station

Pumping stations are vulnerable for wide range of operational problems from malfunction of equipment, loss of power to vandalism when unmanned. Provision shall be made to facilitate easy removal of pumps and motors for periodical repair and maintenance. Monitoring systems such as on-site warning lights and remote alarms will minimize failures and will facilitate in early maintenance of equipment.

The capacity of the sump shall be decided upon future increase in flow due to change of land use. Pump selection procedure is to establish a criteria and then to select a combination from the options available, which meets design criteria. Pumps shall invariably be controlled basically by water level sensor automatic start-stop operating mechanism in addition to manual system. Also depending on the location, pump with variable speed drives with sensor controlled shall be used to match pumping rate precisely with inflow rates. Multiple pumps shall be in place as alternate arrangement. The discharge system to gravity mains shall be as quick as possible. The discharge piping shall be easy to handle.

Maintenance

The best overall procedure for proper functioning of a pump station will be implementation of a schedule for maintenance with a maintenance manual in place. Pumps shall be checked and serviced before monsoon. All defective and worn-out parts shall be replaced. In case of usage of generator for back up, same shall also be tested and kept in working condition.

12 MAINTENANCE OF DRAINS

12.1 The capital cost involved in construction of drains is less than of the total expenditure involved in providing the infrastructure in the form of carriageway, footpaths, medians, street lights and other street furniture. Like any other capital asset, storm water drainage system also needs constant maintenance, if the investment is to serve the purpose meant for. The need for a good storm water drainage or absence of it is felt during monsoon. However, the adverse effect of weak or damaged road crust due to ponding of water and saturation of subgrade continues for a fairly longer period and has to be clearly understood by the engineering fraternity.

12.2 The drainage system is at its best, when it is maintained properly as designed. For this purpose, it is necessary that the drains keep their shape and slope in the designed manner during their life time. It is also necessary to ensure that the drains retain their full cross section, particularly for the monsoons. The system of maintenance can be classified into following three categories.

a) Continuous regular maintenance
b) Periodical maintenance
c) Special maintenance/Repairs for improvement

The extent of these repairs depends upon size of the drain, location of the drain, nature of habitation nearby and cross drainage structures. The difficulty in maintenance is also caused by a lesser degree of consciousness/civic sense. Malba, garbage, solid waste and road cleanings enter the drain resulting in silting and solidification of extraneous material making the maintenance difficult and reducing efficiency. A broad check list is given below.

Broad Checklist for Maintenance of Drains

1) Pavement crown or cross slope is maintained in design profile conducive to quick drainage.

2) Road shoulders are clear and dressed for efficient clear off.
3) If there is a need for new side drain chutes in high embankment.
4) If the kerb channel is clean and slopes towards the inlet is to be provided
5) If the kerb inlets/bell mouths are clear
6) The drain is desilted before rainy seasons, all manholes and grit chambers are cleaned.
7) Inspection after heavy rains is required to know the deficiencies in the system and reporting unsatisfactory performance and also rectifications.
8) Inspection in October/November can be carried out and list defects for summer maintenance
9) Gratings/metallic covers should be checked before monsoon for repair or replacement if any.
10) Discourage & enforce street, house sweeping being dumped into open drains or gutter openings

12.3 Periodical inspection and maintenance of drains is very necessary, as failure of drains will occur due to deficiency in maintenance. The principal activities in maintenance are:

a) Desilting
b) Clearing of weeds
c) Cleaning of obstruction, debris and blockage
d) Repairing of lining immediately at the commencement of damage or deterioration

12.4 Continuous action and attention in detail are important aspects pertaining to maintenance programmes. It is very essential that maintenance units should have all the drawings of existing drains showing all technical details on ground. The drain should be identified by suitable numbering with proper chainage. It should be the endeavor to ensure that works are maintained as per details shown in the inventory prepared just after completion of the drainage scheme.

12.5 The maintenance manual should indicate clearly the work to be carried out. The frequency for that work, the equipment and labour to be used and most important, any safety measures and equipment required. The cleaning is required for all the elements namely, the kerb channel, bell mouth, the pipe, grit chamber/inspection chamber and the drain. Though, it is not practicable to assign individual frequencies for each element as a routine for each area, it should be such as to ensure that all elements are cleaned before the drain gets blocked. For different localities, it may have to be based on local experience.

12.6 It is a common practice that all drains are desilted thoroughly before onset of monsoon. All kutcha side drains shall be dressed and deepened before monsoon. It is also essential that all the drains are in a state of good condition and works regarding, reshaping

or profile correction, wherever required is completed well before the onset of monsoon. In case of pipe drains, if it is not possible to desilt it manually, suitable mechanical devices, as described in clause 12.10 shall be employed. Success of such operation can be ensured only through proper inspection by all field officers rather than leaving it only to maintenance gangs. Outfall structures and the cross drainage structures also require similar treatment.

12.7 During the rains also, there is a need to monitor at the exit and entry point of water for the presence of undesirable collection of rubbish, polythene/paper bags blocking the passage of water and in everyway ensuring free unobstructed flow of rain water. The condition of road camber also needs to be watched. During rains, specially after heavy showers, all cross drainage structures should be inspected to observe any blockage due to debris, log of wood and other such materials. After that, the deficiencies in the drainage system should be assessed and problem locations identified and record kept updated. Necessary corrective measures should be implemented immediately after rains. The missing manhole if any covers and broken covers are also required to be identified and replacement/repairs need to be carried out on priority to avoid accidents.

12.8 Some of the common deficiencies encountered in road drains and suggested remedy is as under:

	Deficiency	Cause	Remedy
i)	Ponding	Inadequate cross-section, formation of depression or settlement in bed, bed erosion	Deepening the drain, re-filling eroded or depressed area.
ii)	Silting	Invert slope inadequate, excess soil entry into the system, less flow compared to design section	Important in slope if possible. Check entry points for silt rubbish etc. measures to concentrate flow to lean season. Provision of grating at entry points
iii)	Blockage due to debris vegetation etc.	Uneven drain bed, absence of maintenance, cleaning	Desilting and cleaning. Provision of grating at entry points
iv)	Erosion of bed and cross section	Steep invert slope, caving in of sides because of lack of lateral support	Provide flatter slope with drops, if needed. Adequate side support, re-alignment, if required.

12.9 Maintenance of Subsoil Drainage

Subsoil drainage uses porous pipes, lateral and vertical layers of granular material and man made fabrics and membrane. Such drainage techniques are largely built in features of the design, and do not lead themselves to routine maintenance. Their presence and the intended mode of operation must be known and understood by the maintenance engineer. Many of

these systems tend to clog over a period of time and may need replacement. In such cases, obvious surface signs, such as flooding, or instability of pavements may be the first warning of the system failure. The most critical aspect of subsoil drainage is the provision of detailed "as built" information or drawings to the maintenance personnel to reduce the risk of inadvertent disruption of intended operation during subsequent maintenance works.

For the purpose of easy identification it would be necessary that location of various inlets, outlets, intermediate pits along the drainage lines is marked using pegs on the ground. Same numbering should be available on the pegs and the drawings also. The following guidelines may be adopted for maintaining the expected performance level of subsurface drains.

a) The drainage system should be inspected at least twice a year out of which at least one should be immediately after heavy rains. The quality and quantity of outflow should be observed and recorded. It is to be noted that pavement drains discharge water, after rains only, whereas drains installed to lower subsoil water table or intercept underground seepage could carry water even in dry season. Muddy water could indicate non functional filter and no flow could indicate a blocked drain.

b) Inlets should be inspected for signs of structural damage, vandalism and blockage and corrective action taken.

c) Outlets should be inspected for scour, structural damage and blockage.

   The routine maintenance consists of removal of siltation, removal of grass and repair of any minor scour.

d) A check should be made to ensure that surface runoff does not enter the subsoil drainage system.

e) A check should be made to ensure that marker pegs are not missing and are visible.

f) Pit covers and frames should be replaced if damaged and pits relocated if damaged frequently.

12.10 Storm Water Drain Cleaning Equipment and Devices

Covered drains and pipes, though solve other problems do not lend themselves to cleaning easily as their size are small. Many a times, the cleaning is done only at the location of manholes or inspection chambers or near the location of removable slabs. This does not give satisfactory level of service as the pipes or the main channel remains blocked and full design cross section is not available. As such it is necessary that proper attention is paid to this aspect and available cleaning equipments and devices are used. In some cases it may be necessary to adopt the commonly used sewer cleaning devices for this purpose.

Covered drains and pipes carrying storm water can be cleaned using following equipment and devices. When cleaning after a dry spell, it would be necessary that water is let into the manholes for the deposited silt to get softened for is removal by mechanical devices.

i) **Portable pump set**

In cases where the drains are blocked completely and water has accumulated in the manhole/ road side, the collected water has to be pumped out to tackle the blockage. Such pumps, should preferably be non clogging type on four wheel trailers and should be of self priming type to save time and effort.

ii) **Sectional sewer rods**

These rods **(Fig. 12.1)** are used for cleaning small lines. These rods may be of bamboo or teakwood or locally available wood or light metal usually about 1m long. The ends have coupling arrangement which remain intact in the line but can easily be disjointed in the manhole. Sections of rods are pushed down the line until the obstruction is reached and dislodged. The front or the advancing end of the rod is normally fitted with a cutting edge to cut and dislodge the obstruction.

Fig. 12.1 Joined Sewer Rods

iii) **Flexible sewer rods**

The flexible rod used in manual cleaning is usually made by sand-witching a manila rope between bamboo strips and tying at short intervals. The flexible rod is introduced first from one manhole to the other, its end being connected to a thicker rope which, when dragged down the line draws out deposited material into the down stream manhole from where it can be removed easily.

iv) **Ferret used in conjunction with a water jet**

This is used for breaking and removing the deposited materials. It uses a high pressure hose connection and produces a small but high velocity stream of water forward in the upstream direction from the central nozzle and several lower velocity jets in the down stream direction. The forward jet loosens the accumulated debris ahead and the rear jet washes it back down stream. This device must be attached to a vehicle carrying necessary capacity water tank and mechanical device which can raise such pressures to reach the next manhole. Also, it must be kept in motion to prevent sand/silt from locking the hose in the line. Now a days these indigenous devices are being regularly used for flushing manholes in sewerage drains.

v) **Bucket machine**

The bucket machine **(Fig. 12.2)** consists of two powered winches with cables in between. The winches are centered over two adjacent manholes. The cable

is threaded through the line by using flexible rods. The cable from the drum of each winch is fastened to the barrel on each end of an expansion bucket fitted with closing device, so that the bucket can be pulled in either direction by the machine on the appropriate end. The bucket is pulled into the pipe line until the operator feels that it is loaded with silt. This motor is then disengaged through a clutch system and the opposing winch is put into action. When the opposite pull is started, the bucket automatically closes and the deposited materials comes out. This operation is repeated till the entire line is clear. This machine is also used along with other scraping instruments for loosening the deposited material or cutting roots and dislodging obstructions.

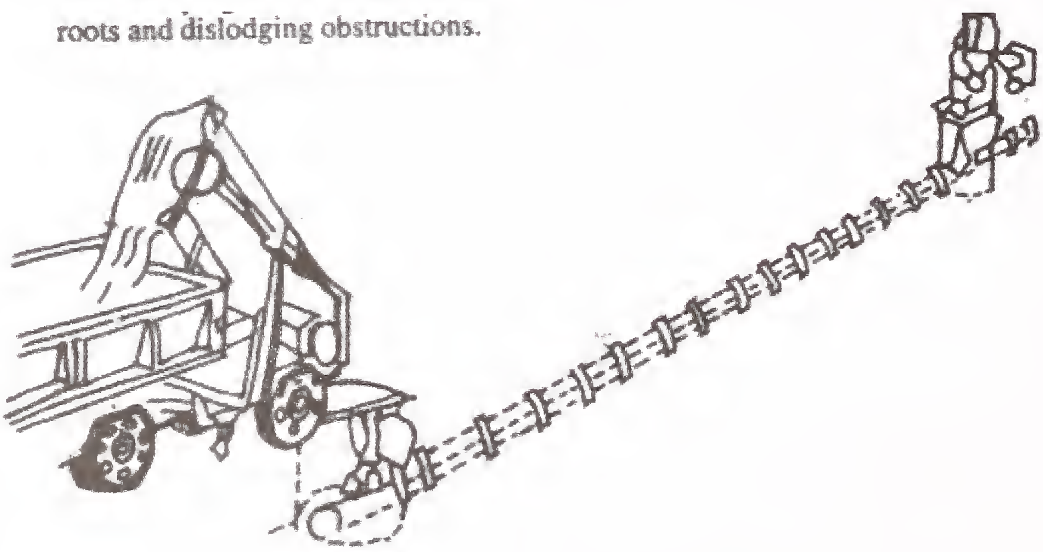


Fig. 12.2 Sewer Cleaning Bucket Machine

vi) Rodding Machine with flexible rods

This consists of a machine which rotates a flexible rod to which a cleaning tool such as auger, corkscrew, sand cups is attached **(Fig.12.3 & 12.4).** The flexible rod consists of a series of steel rods with screw couplings. The flexible rod is guided into the manhole through a bent pipe. The machine rotates the rod with cleaning tool **(Fig. 12.5)** attached to the other end. The rotating rod is pulled in and out in quick succession so as to dislodge or loosen the obstruction when the obstruction is cleaned, the rod is pulled out by means of clamps.

vii) Scraper

This method is used for pipes of dia larger that 750 mm. The scraper is an assembly of wooden planks of slightly smaller size then the pipe to be cleaned. The scraper chain, which is attached to the scraper is connected to a winch on the next downstream manhole by means of chain. The winch is then operated to push the debris ahead of the scraper. The heading up of flood behind the scraper will also assist in pushing it in the forward direction.

Fig. 12.3 Rodding Machine with Flexible Sewer Roads

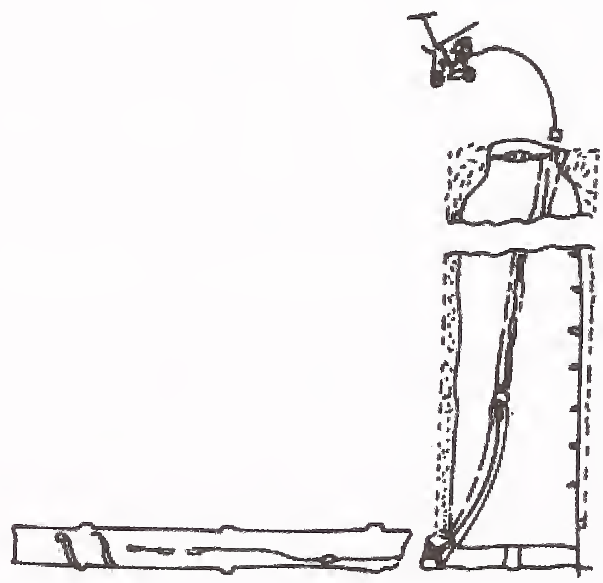
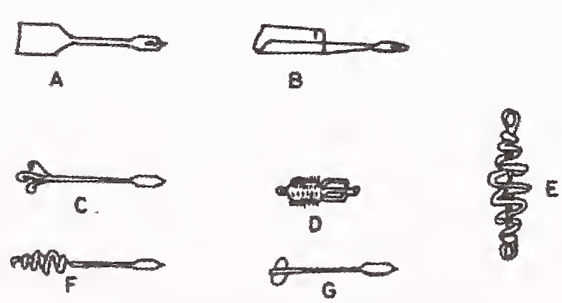


Fig. 12.4 Power operated steel flexible rods



A GOUGE FOR CUTTING OBSTRUCTIONS
B SCOOP TO REMOVE SAND AND LOOSE MATERIAL.
A FLAPGATE ON THE END IS DESIRABLE
C&F CLAW AND SEREW FOR REMOVING PAPER AND RAGS
D BRUSH FOR REMOVING GREASE
E ROOT CUTTER
G SCRAPER

Fig. 12.5 Sewer cleaning tools

viii) Hydraulically propelled rubber balls

The ball used is of soft rubber and is inflated to slightly lesser diameter than the pipe. A rope is attached to the ball and it is allowed, to travel from a manhole downstream in the pipe. The ball adjusts itself to the irregularities in the pipe, but the water held behind it escapes in a strong stream between the ball and the pipe thus flushing the debris. Some of the balls have spiraled ribs which impart a rotary motion to the water on the downstream side. Others are enclosed in a light chain network or a canvas cloth.

12.11 In case of blockage of drain due to settlement, the drain section is required to be repaired after locating the settled portion.

13 ENFORCEMENT FOR CLEANING DRAINS

13.1 Enforcement of Cleaning the Drains

13.1.1 Majority of Urban Local Government Bodies in the Country are enforcing the practice and periodic silt removal and have become more conscious about restriction and disposal of debris in to storm water drains. As since large quantum of public funds are spent on storm water drainage implementation, time has come for enforcement of certain disposable systems where in the offending party shall be penalized and booked under various punitive clauses of respective local urban bodies. This practice is already in force and is being continued in many Urban Local Government Bodies.

13.1.2 All vulnerable stretches of drains which are thickly populated and where debris is likely to be thrown into the drain shall be fenced suitably.

13.1.3 In light of serious choking of storm water drains by reckless disposal of debris, punitive action like criminal proceedings with respective state municipal acts shall be imposed, in addition, larger corporations shall deploy patrolling vehicles for containing the same. Some cities have already implemented this provision.

13.1.4 Silt removal from open channel drains and covered drains shall be carried out as and when the channel is filled to the extent of twenty percent or more of cross sectional area of drain. The silt removal from the drain shall be carried out straight to waiting disposal vehicle in all urban locations other than central business district. The silt shall not be stacked adjacent to the drain. In CBD area's when disposal vehicles cannot wait on the road due to traffic conditions, silt can be stacked adjacent to drain and loaded to vehicle within 6 – 8 hours of removal of silt, preferably during nights or when traffic is lean. Social, administrative and punitive measures shall be imposed to see that these open drains are not used as trash collectors. Offenders shall be penalized under respective penal clauses of urban local body.

13.1.5 Most primary and secondary drains in Urban Local Bodies have been encroached upon reducing the width of valleys. The discharge capacity gets reduced leading to flooding in populated localities. City survey maps will provide information about original width of conveying drains and all encroachments shall be removed and the original width of drain shall be restored.

13.1.6 No residential or commercial structure shall be constructed on any type of storm water drains. In case of existing ones, same shall be removed.

13.1.7 Service roads shall be constructed on either side of storm water primary/secondary drains for movement of maintenance vehicles.

14 GEOGRAPHICAL INFORMATION SYSTEM – MASTER PLAN

14.1 The drainage guidelines will work most effectively under a larger framework of a Comprehensive drainage master plan that will manage stormwater based on watershed based planning, that directs water based on natural topography of the region, focusing on retaining and recharging water locally as in pre-development conditions.

14.2 In the earlier period, all the storm water drains, tertiary primary & secondary were exposed in every town and cities. Due to phenomenal growth of cities and towns, these drains are covered, encroached & realigned. It is desirable a GIS (Geographic Information System) based master plan is prepared based on the analysis of drainage patterns, hydrological mapping, topography and open spaces of the city. It will help identify watersheds, critical aquifer recharge zones, ecologically sensitive riparian zones and other green areas of the city that need to be preserved for their role in sustainable urban drainage system.

In addition, master plan may be prepared for storm water drains in every city & town indicating the type of drain, cross sectional area and also rehabilitation mentioning the return period. Some of the cities have already prepared, proposal master plan covering primary and secondary drains which collect water from road side tertiary drains and road surface. This covers alignment of drains/service roads and also any widening required as per design on return for upto 5 years, based on which the width of the channel is arrived at. A map of city indicating the alignment of drains is shown in **Fig. 14.2. (i).**

14.3 **The key objectives of a drainage master plan are:-**

1) Protecting the existing waterways
2) Reducing run off by using natural drainage mechanisms
3) Facilitating low (environmental) impact development.
4) recharging ground water
5) maintaining quality of water
6) Maintaining health of eco-systems
7) Building resilience of the stormwater system
8) Formulation of guidelines for design, construction, operation and maintenance

14.4 **Essential Components**

14.4.1 *Watershed planning*

14.4.2 *Designing of decentralized systems viz.*

a) Permeable surfaces;
b) Filter strips;
c) Filter and infiltration trenches;

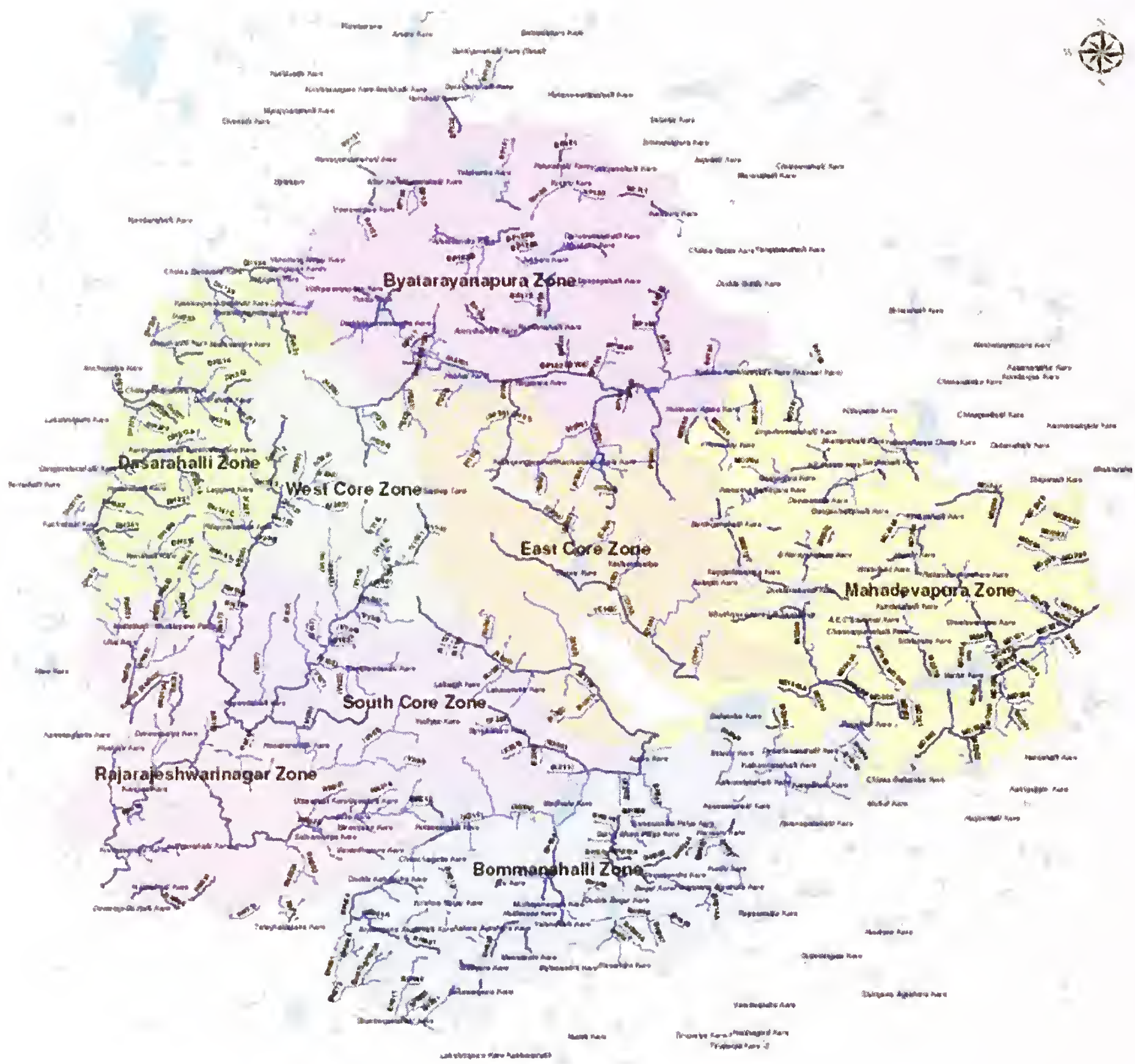


Fig 14.2. (i) City Plan Showing Alignment of Primary & Secondary Drains

d) Bio-Swales;
e) Detention basins;
f) Underground storage;
g) Wetlands;
h) Ponds.

Planning of storm water system capacity based on expected rainfall quantum (analysis of 50 years and 100 years flooding history), looking into water absorption quotient of soil types in question as well as critical aquifer recharge zones working in a coherent manner within decentralized systems listed above. The constructed/ structured drainage system will be designed to take additional run-off from intense peak hour rainfall and direct it to closest detention areas or to closest water course. The overall aim is to spread and soak water in natural and designed low areas (roadside greens, bio swales, filter strips, etc.) so that it recharges closest to where it falls. The natural systems primarily act as conveyance channel of stormwater whereas structured systems supplement them, to protect the existing water ways, to formulate guidelines for design, construction, operation and maintenance of the system

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